US/USSR
COOPERATIVE SPACE LABORATORY
(SKYLAB/SALYUT)

23 JUNE 1972

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
EASTERN DIVISION

Saint Louis, Missouri 63166 (314) 232-0232

MCDONNELL DOUGLAS
CORPORATION

COOPERATIVE SPACE MISSION

OBJECTIVES

- PROVIDE PROGRAM OF INTERNATIONAL COOPERATION
  - DEMONSTRATE LONG-TERM SIDE-BY-SIDE LIVING/WORKING ARRANGEMENT
  - MUTUAL TECHNOLOGICAL BENEFITS AND COST SAVINGS THRU THE USE OF EACH COUNTRY'S EXPERIMENTAL LABORATORY
- PROVIDE IDENTIFIABLE BENEFITS FROM SPACE
- ADDRESS WORLD NEEDS AND REQUIREMENTS FOR TECHNOLOGY DEVELOPMENTS
- PROVIDE EVOLUTIONARY STEP BETWEEN SKYLAB A AND SPACE SHUTTLE/STATION
- PRUDENT USE OF "PAID FOR" SKYLAB BACKUP HARDWARE

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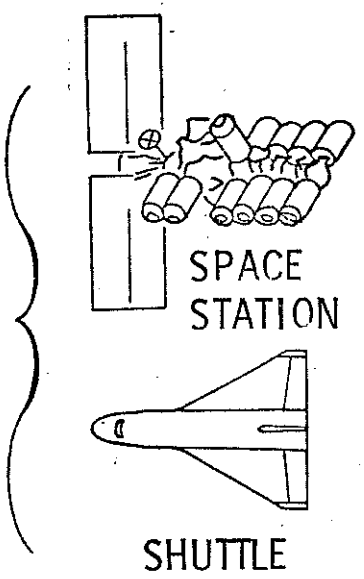
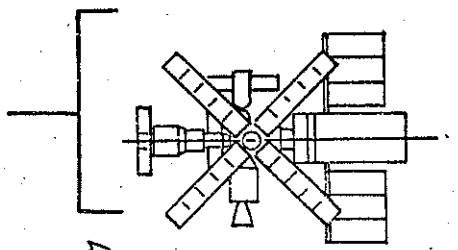
COOPERATIVE SPACE MISSION

CANDIDATE LABORATORY IS A LOGICAL STEP IN MANNED SPACE FLIGHT EVOLUTION AND HELPS FILL THE VOID BETWEEN SKYLAB-A AND SHUTTLE

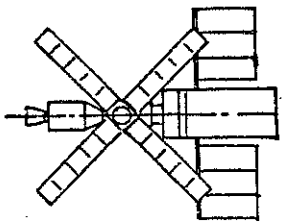


COOPERATIVE MISSION:

TO DEMONSTRATE A UNIQUE AND SELF-SUPPORTING INTERNATIONAL SPACE STATION



INTERNATIONAL DOCKING



SKYLAB-A

APOLLO

1968 - 72 | 1973 - 74 | 1975 | 1976 | 1979

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COOPERATIVE SPACE MISSION
GUIDELINES

- FOLLOW 6 DECEMBER 1971 US/USSR AGREEMENTS EXCEPT:
  - 140 DAY MISSION (SAME AS SKYLAB A)
    - 2 CSM'S ON 70 DAY CENTERS
  - 235 NM (436 KM) ALTITUDE (SAME AS SKYLAB A)
    - PROVIDES LONG LIFE CAPABILITY
  - PROVIDE ALTERNATES FOR OPERATING PRESSURE
    - US OPERATES AT 5 PSIA
    - CSM AND SKYLAB STRUCTURALLY CAPABLE OF 8 PSIA OPERATION

- ADDITIONAL GUIDELINES
  - NO POWER TRANSFER BETWEEN US AND USSR VEHICLES
  - SKYLAB PROVIDES CLUSTER ATTITUDE CONTROL
  - SKYLAB PROVIDES SUPPORT FOR THREE MEN; SALYUT PROVIDES SUPPORT FOR THREE MEN

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COOPERATIVE SPACE MISSION
US/USSR AGREEMENTS COMPARISON

	AGREEMENT *	SALYUT	SKYLAB
ATMOSPHERE	$N_2 - O_2$	$N_2 - O_2$	$N_2 - O_2$
PRESSURE	760 ± 15 mm Hg	760 mm Hg	260 mm Hg
PPO_2	160 ± 15 mm Hg	195 mm Hg	192 mm Hg
PP H2O	8 TO 12 mm Hg	UNK	8-13 mm Hg
PP CO_2	7 mm Hg	8.5 mm Hg	5.5 mm Hg
TEMPERATURE	20° ± 5° C	17-22° C	24° ± 9° C
CLEAR HATCH DIAMETER	.8 METER	.7 METER	1.2 METER (AM) .8 METER (CSM)
ALTITUDE	250-300 KM	250-500 KM (EST)	435 KM
INCLINATION	51.6°	51.6°	50°
COMMUNICATION FREQUENCY			
US	100-300 MHz	----	235 MHz
USSR	121.75 MHz	UNK	----
MISSION DURATION	2 DAYS	24 DAYS	140 DAYS
DOCKING PARAMETERS			
CLOSING VELOCITY	.05-.3 M/SEC	UNK	----
CONTACT VELOCITY	.03 M/SEC	UNK	.3M/SEC
LATERAL VELOCITY	.1 M/SEC	UNK	.15M/SEC

* MINUTES OF US/USSR DISCUSSIONS DEC. 6, 1971

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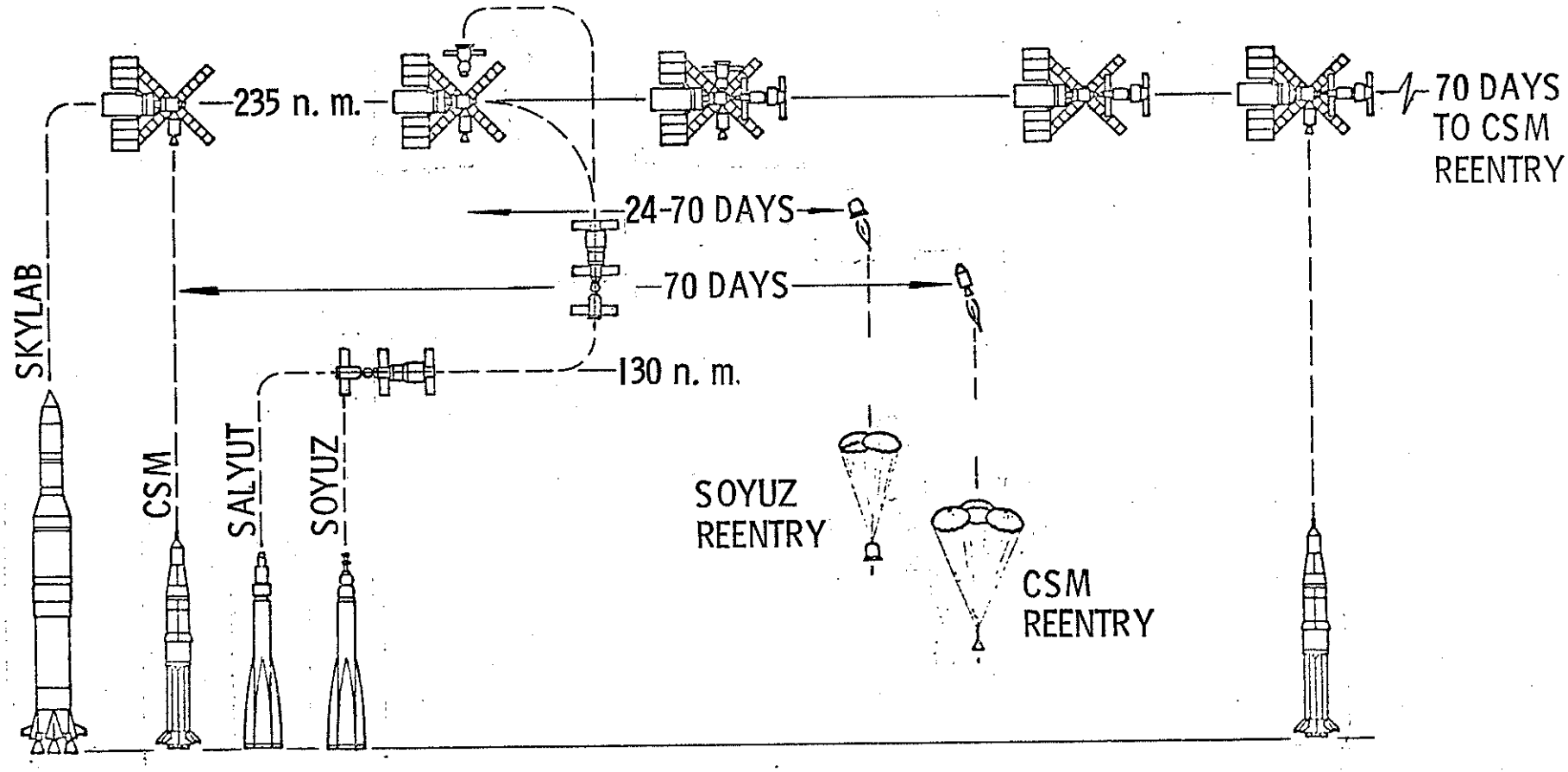
COOPERATIVE SPACE MISSION

MISSION OBJECTIVE IS TO COMBINE THE RUSSIAN SALYUT AND SOYUZ WITH AN AMERICAN SKYLAB TO FORM A COOPERATIVE SPACE LABORATORY



MISSION PROFILE

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COOPERATIVE SPACE MISSION
MISSION SEQUENCE

- o SKYLAB LAUNCHED TO 235 NM
  - o CSM LAUNCHED TO 81 x 120 NM ORBIT
  - o CSM TRANSFERS TO 235 NM AND DOCKS WITH SKYLAB
- o SALYUT LAUNCHED TO 130 NM ORBIT
- o SOYUZ LAUNCHED TO 130 NM ORBIT AND DOCKED WITH SALYUT
  - o SALYUT TRANSFERS SOYUZ TO 235 NM
    - o USSR CREWMAN DOCK SALYUT WITH SKYLAB
    - o USSR CREWMEN DOCK SOYUZ WITH SKYLAB

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COOPERATIVE SPACE MISSION
ORBIT SELECTION

INCLINATION 51.6°

- o COMPATIBLE WITH SOYUZ/SALYUT LAUNCH
- o DECREASED SKYLAB AND CSM PAYLOAD
  - o APPROX 800 LBS AND 200 LBS RESPECTIVELY FROM 50°

ALTITUDE 235 N.M.

- o 130 n.m. PRESENT USSR OPERATIONS
- o USSR VEHICLES HAVE ADEQUATE CAPABILITY TO TRANSFER TO HIGHER (> 235 n.m.) ORBIT
- o SKYLAB 235 N.M. - SUFFICIENT LIFETIME FOR 2 CSM MISSIONS AND MAXIMUM UTILIZATION OF EXPERIMENT PROGRAMS

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COOPERATIVE SPACE MISSION

PROGRAM CHARACTERISTICS

ORBITAL PARAMETERS:	235 n. m. X 51.6° INCLINATION
WORKING VOLUME:	15,000 FT^3
CREW:	6 (3 USA, 3 USSR)
MISSION DURATION:	US: 140 DAYS (TWO CSM VISITS AT 70 DAY CENTERS) USSR: 24-140 DAYS (DEPENDING ON NUMBER OF SOYUZ'S)
LAUNCH:	MID 1976
EXPERIMENTS:	SOLAR, STELLAR, EARTH RESOURCES, COMMUNICATION, TECHNOLOGY, MEDICAL

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COOPERATIVE SPACE MISSION LABORATORY CAPABILITY

US AND USSR SPACECRAFT CAN SUPPORT A MEANINGFUL SPACE LABORATORY EXPERIMENT PROGRAM
THE CANDIDATE MANNED SPACE LABORATORY WILL PROVIDE ADDITIONAL EXPERIMENT ACCOMMODATION AND CREW TIME TO PERFORM USEFUL EXPERIMENTS

	SKYLAB	SALYUT
o MISSION DURATION	UP TO 18 MONTHS	7 MONTHS (DEMONSTRATED)
MANNED	4 TO 5 MONTHS	1 MONTH (DEMONSTRATED) 4 MONTHS (ESTIMATED)
UNMANNED	7 TO 14 MONTHS	5 MONTHS (DEMONSTRATED)
o EARTH RESOURCES PASSES	250 TO 500	UNKNOWN
o EXPERIMENT ACCOMODATIONS		
VOLUME - INTERNAL	4500 FT^3	1000 FT^3 (ESTIMATED)
WEIGHT		
TOTAL	18000 LBS	4000 LBS (ESTIMATED)
o CREW TIMELINE		
CREWMAN - TOTAL	3	3
CREWMAN - OVERLAP	6	-
EXPERIMENTS	1000 MAN-HRS / MO.	1000 MAN-HRS / MO.

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COOPERATIVE SPACE MISSION EXPERIMENT PROGRAM

- COORDINATED INTERNATIONAL EXPERIMENTS IN LARGE SKYLAB / SALYUT RESEARCH LABORATORY HAS MANY BENEFITS
  - NEW "SUITCASE" CARRY-ON EXPERIMENTS - USA AND INTERNATIONAL
  - USSR PARTICIPATION IN SOLAR INVESTIGATIONS USING SKYLAB SOLAR TELESCOPE MOUNT
  - JOINT UTILIZATION OF USA/USSR SENSORS FOR WORLD-WIDE EARTH RESOURCE SURVEY
  - OPPORTUNITY TO EVALUATE MEDICAL DATA USING 6 MEN
    - CAN COMPARE TO 5 PSIA AND 15 PSIA USA/USSR DATA POINTS
  - JOINT UTILIZATION OF USA/USSR EXPERIMENTS IN ASTRONOMY, TECHNOLOGY AND CREW OPERATIONS

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COOPERATIVE SPACE MISSION
EXPERIMENT COMPARISON

SKYLAB A (1973 LAUNCH)

GUIDANCE AND NAVIGATION
NONE

EARTH RESOURCES
MULTISPECTRAL PHOTOGRAPHY
INFRARED SPECTROMETER
10-BAND MULTISPECTRAL SCANNER
MICROWAVE SCATTEROMETER
L-BAND RADIOMETER

BIOMED
MINERAL BALANCE
BONE DENSITOMETRY
BIOASSAY OF BODY FLUIDS
SPECIMEN MASS MEASUREMENT
LOWER BODY NEGATIVE PRESSURE
VECTORCARDIOGRAM

SALYUT (1971 LAUNCH)

GUIDANCE AND NAVIGATION
ORIENTATION OF STATION
NAVIGATION OF STATION
MANEUVERING IN ORBIT

EARTH RESOURCES
SPECTOGRAPHIC FILMING OF LAND AND OCEAN
SNOW AND ICE COVER
GEOLOGICAL FORMATIONS

BIOMED
CARDIO-VASCULAR SYSTEM
BLOOD SAMPLES
SOCIAL INTERACTION OF CREW
BONE TISSUE
VISUAL ACUITY AND EYEBALL CONVERGENCE

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COOPERATIVE SPACE MISSION
EXPERIMENT COMPARISON (CONTINUED)

BIOMED (CONTINUED)

- BLOOD CELL STUDIES
- HUMAN VESTIBULAR FUNCTION
- SLEEP MONITORING
- TIME AND MOTION STUDY
- METABOLIC ACTIVITY
- ZERO-G HUMAN CELLS
- CIRCADIAM RHYTHM - MICE AND VINEGAR GNAT

CREW OPERATIONS

- EVA AND IVA HARDWARE EVALUATION
- MANEUVERING EQUIPMENT
- PRECISION OPTICAL TRACKING
- CREW/VEHICLE DISTURBANCES

COMMUNICATIONS

- NONE

BIOMED (CONTINUED)

- GENETICS (MUTATIONS)
  - o FRUIT FLIES
  - o YEASTS
  - o CHLORELLA
  - o PLANT SEEDS
  - o HAWK'S BEARD (PLANT)
  - o FROGS EGGS

CREW OPERATIONS

- UNKNOWN

COMMUNICATIONS

- HF RESONANCE ON ANTENNAS IN SPACE

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COOPERATIVE SPACE MISSION
EXPERIMENT COMPARISON (CONTINUED)

ASTRONOMY

SOLAR
- WHITE LIGHT CORONOGRAPH
- X-RAY SPECTROMETRY
- X-RAY UV SOLAR PHOTOGRAPHY

STELLAR
- UV STELLAR ASTRONOMY
- GEGENSCHEIN ZODIACAL LIGHT
- GALACTIC X-RAY MAPPING

GENERAL
- UV PANORAMA
- PARTICLE COLLECTION
- UV AIRGLOW HORIZON PHOTOGRAPHY
- NUCLEAR EMULSION

AGRONOMY

NONE

ASTRONOMY

SOLAR
- UNKNOWN

STELLAR
- UV STELLAR RADIATION
- STELLAR SPECTROPHOTOMETRY

GENERAL
- UNKNOWN

AGRONOMY

VEGETATION DEVELOPMENT
- o CHINESE CABBAGE
- o FLAX
- o ONIONS
- o KALE

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COOPERATIVE SPACE MISSION

EXPERIMENT COMPARISON (CONTINUED)

TECHNOLOGY

- INFLIGHT AEROSOL ANALYSIS
- CONTAMINATION MEASUREMENT
- RADIATION IN SPACECRAFT
- THERMAL CONTROL COATINGS
- ZERO-G FLAMMABILITY
- MATERIAL PROCESSING IN SPACE

TECHNOLOGY

UNKNOWN

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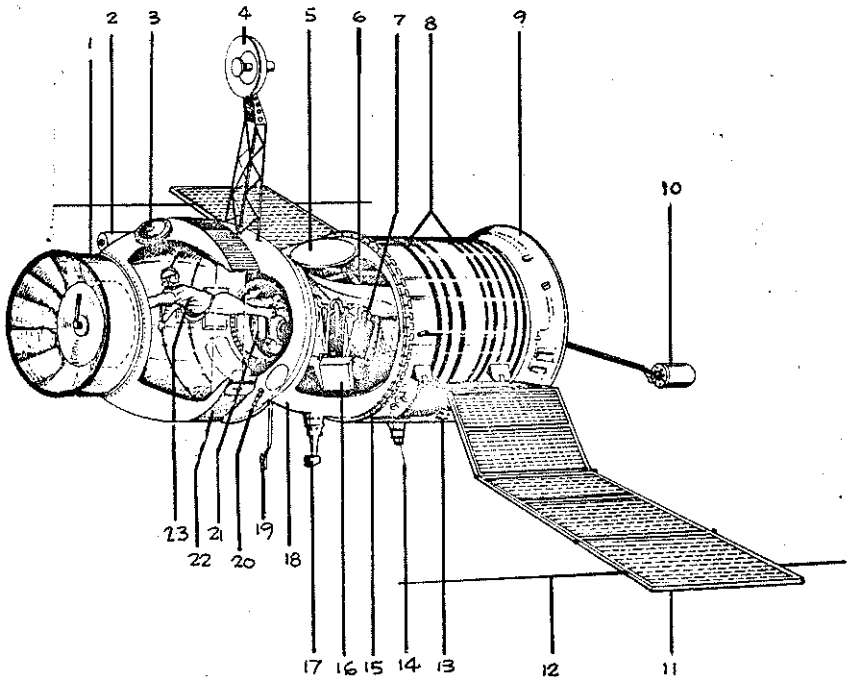
COOPERATIVE SPACE MISSION
USSR SPACECRAFT DESCRIPTION

SOYUZ

- FUNCTION IS EQUIVALENT TO CSM'S
  - CREW TRANSPORT AND REENTRY VEHICLE
- REMAINS DORMANT AT LABORATORY



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COOPERATIVE SPACE MISSION
USSR SPACECRAFT DESCRIPTION
SOYUZ LEGEND

1. DOCKING TUNNEL OF TRANSPORT VEHICLE
2. TELEVISION CAMERA
3. PORTHOLE
4. NAVIGATION ANTENNA (USED DURING RENDEZVOUS)
5. HATCH FOR PARACHUTE SYSTEM
6. PARACHUTES (1 STABILIZATION, 1 MAIN, 1 BACKUP)
7. SEATS
8. RADIATORS TEMPERATURE CONTROL SYSTEM
9. SKIRT OF PROPULSION SECTION
10. SEARCH ANTENNA
11. SOLAR PANELS (2 ON SOYUZ)
12. ANTENNA (COMMUNICATION)
13. SOYUZ SERVICE MODULE
14. SENSOR ORIENTATION SYSTEM
15. TELEMETRY ANTENNA
16. INSTRUMENT PANEL
17. ORIENTATION DEVICE (USED DURING MANEUVER RENDEZVOUS AND DOCKING)
18. SOYUZ COMMAND MODULE
19. BEACON LIGHT
20. ROLL CONTROL JETS
21. COMMAND MODULE HATCH
22. SOYUZ ORBITAL MODULE
23. COMMANDER

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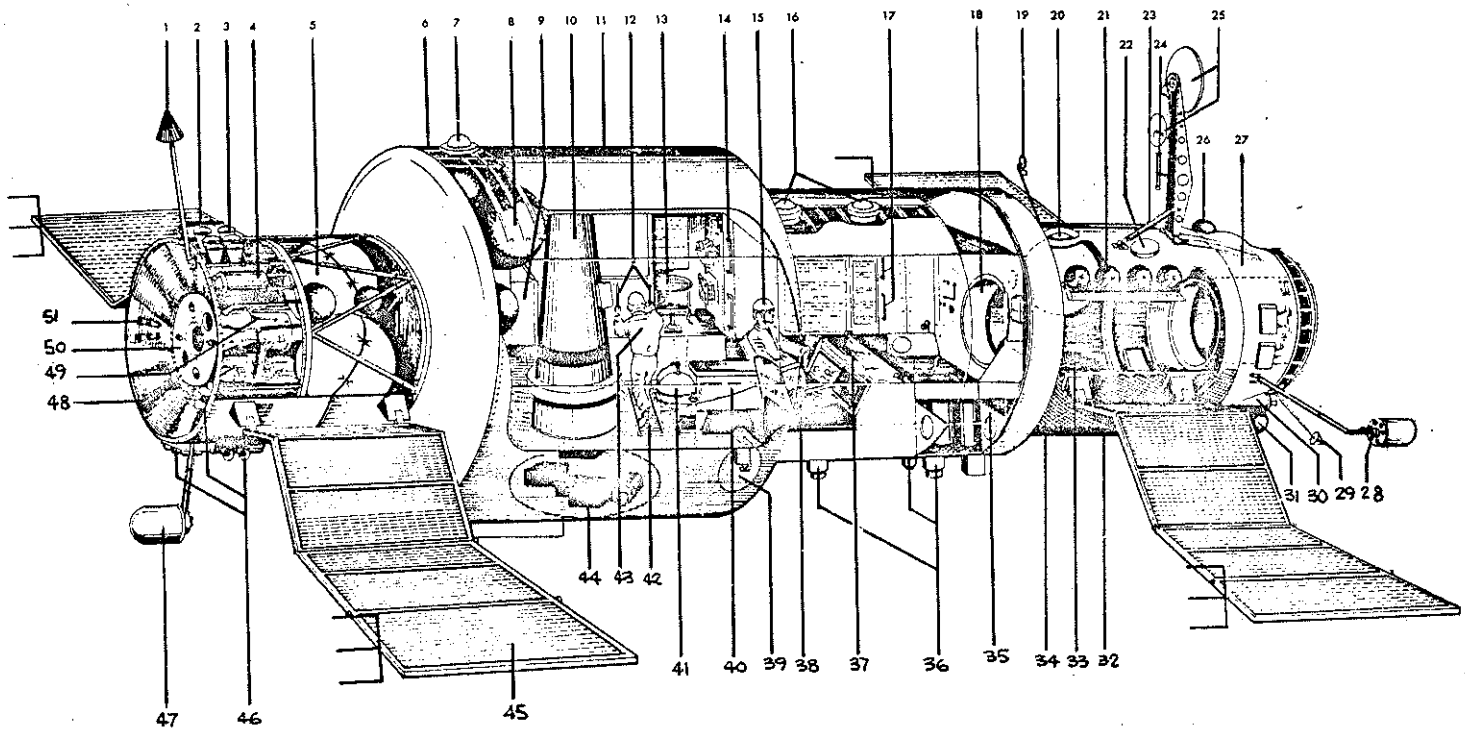
COOPERATIVE SPACE MISSION
USSR SPACECRAFT DESCRIPTION

SALYUT

- FUNCTION IS EQUIVALENT TO SKYLAB'S
- HAS 3500 FT^3 OF VOLUME
- SELF-SUPPORTING FOR 3 MAN CREW
- PROVIDES ADDITIONAL EXPERIMENT CAPABILITY



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COOPERATIVE SPACE MISSION
USSR SPACECRAFT DESCRIPTION
SALYUT LEGEND

1. SEARCH ANTENNA
2. TELEVISION CAMERA
3. MICRO-JETS FOR ATTITUDE CONTROL
4. TELEVISION CAMERA
5. FUEL TANK
6. PART OF SERVICE MODULE OF SALYUT
7. REFUELLING POINT
8. TANK OF LIFE SUPPORT SYSTEM
9. CONTROL PANEL OF SERVICE MODULE
10. "CHIMNEY" CONNECTED WITH EQUIPMENT BAY (35)
11. WORKING COMPARTMENT
12. HANDHOLDS
13. SEAT FOR MEDICAL EXAMINATION
14. HANDHOLDS
15. COMMANDER (LEFT SEAT)
16. PORTHOLES
17. HANDHOLDS
18. HATCH
19. BEACON LIGHT
20. ASTROPHYSICAL SYSTEM (ORIAN)
21. SPHERICAL COMPRESSED GAS CONTAINERS
22. PORTHOLE
23. JACK TO ERECT ANTENNA
24. ATTITUDE CONTROL JETS
25. NAVIGATION ANTENNA USED DURING RENDEZVOUS
26. SPHERICAL GAS CONTAINERS (PART OF "RING" ENDING WITH 31)
27. DOCKING TUNNEL OF ORBITAL STATION
28. SEARCH ANTENNA
29. OMNIDIRECTIONAL ANTENNA
30. TELEVISION CAMERA
31. SPHERICAL GAS CONTAINER (SEE 26)
32. TRANSFER COMPARTMENT OF SALYUT
33. SLEEPING BAG
34. OUTER PROTECTIVE COVER
35. EQUIPMENT SECTION
36. SENSORS AND OBSERVATION EQUIPMENT
37. CENTRAL INSTRUMENT AND CONTROL PANELS
38. SEAT OF FLIGHT ENGINEER
39. PORTHOLE WITH EQUIPMENT STOWAGE
40. TABLE WITH FOOD CONTAINERS
41. DRINKING WATER TANK WITH 3 HOSES
42. TREADMILL

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COOPERATIVE SPACE MISSION
USSR SPACECRAFT DESCRIPTION
SALYUT LEGEND
(CONTINUED)

43. COSMONAUT DOING PHYSICAL EXERCISE
44. EQUIPMENT STOWAGE
45. SOLAR PANEL ORBITAL STATION
46. STABILIZATION AND ATTITUDE CONTROL JETS
47. SEARCH ANTENNA ORBITAL STATION
48. PROTECTIVE SKIRT OF THRUST UNIT
49. COMBUSTION CHAMBERS OF 3 MAIN ENGINES
50. EXHAUST NOZZELS OF 3 MAIN ENGINES AND 4 ATTITUDE JETS
51. ATTITUDE JETS

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COOPERATIVE SPACE MISSION CONFIGURATION

BASELINE

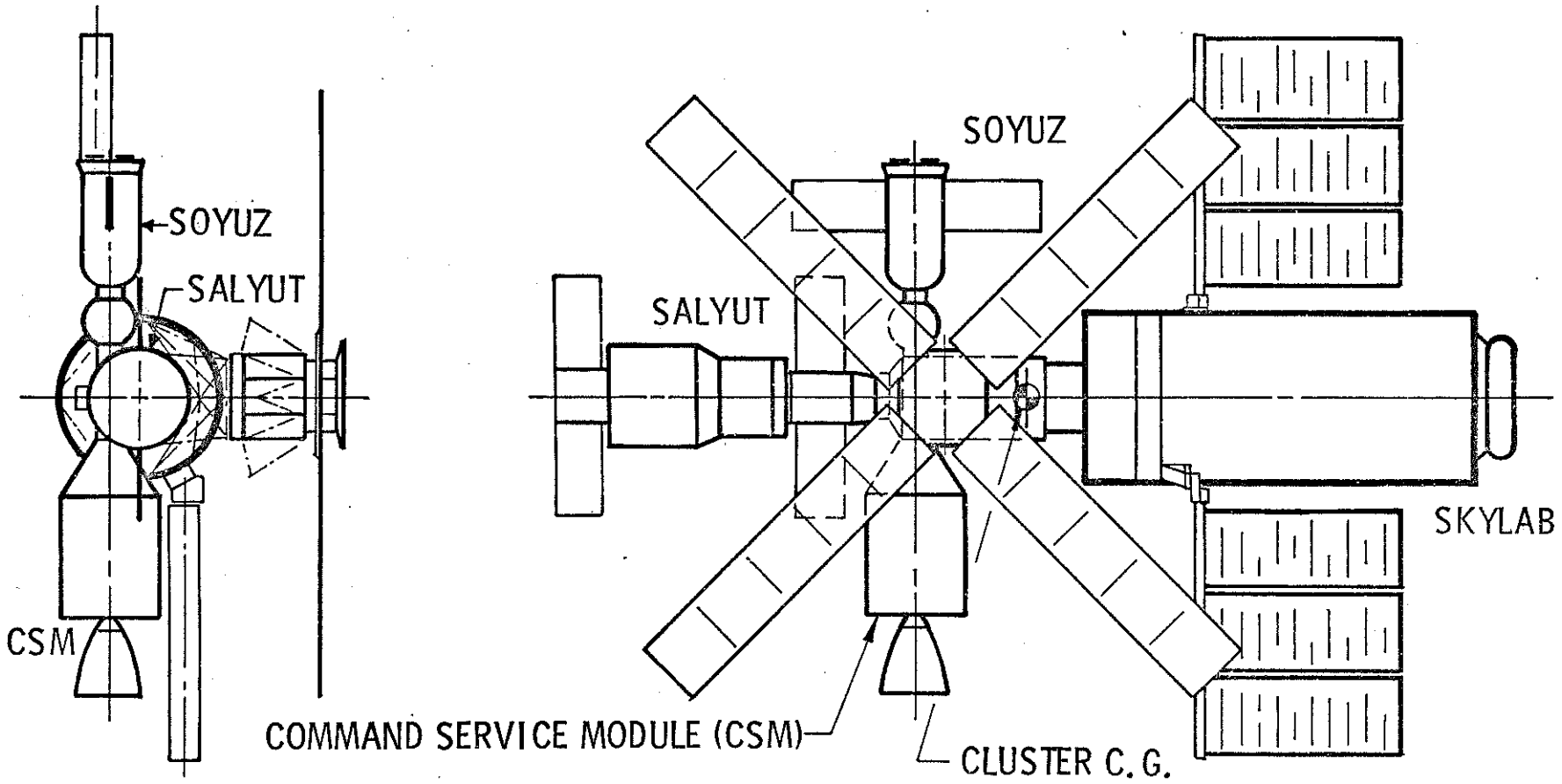
5 PSI OPERATING PRESSURE

ALTERNATE I

15 PSI OPERATING PRESSURE

ALTERNATE 2

8 PSI OPERATING PRESSURE



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COOPERATIVE SPACE MISSION
MODIFICATION SUMMARY

- REQUIRED CHANGES
  - SKYLAB
    - PROVIDE NEW DOCKING PORTS WITH INTERNATIONAL DOCKING MECHANISM
    - RELOCATE MULTIPLE DOCKING ADAPTER RADIATOR TO FAS
    - UPRATE CMG'S
    - ADD S-BAND COMMUNICATIONS
    - ADD ATMOSPHERE INTERCHANGE DUCT ACROSS SALYUT INTERFACE
    - ADD HARDLINE COMMUNICATIONS LINK ACROSS SALYUT INTERFACE
    - ADD COMPATIBLE RENDEZVOUS AND DOCKING AIDS
  - CSM
    - ADD HEATERS
  - SALYUT
    - ADD INTERNATIONAL DOCKING MECHANISM
    - COMPENSATE FOR 25% SHADOWING OF SOLAR ARRAY
    - ADD PROVISIONS FOR ATMOSPHERE INTERCHANGE DUCT ACROSS SKYLAB INTERFACE
    - ADD PROVISIONS FOR HARDLINE COMMUNICATIONS LINK ACROSS SKYLAB INTERFACE
    - ADD DOCKING STATION
  - SOYUZ
    - ADD INTERNATIONAL DOCKING MECHANISM
    - ADD COMPATIBLE RENDEZVOUS AND DOCKING AIDS

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COOPERATIVE SPACE MISSION
MODIFICATION SUMMARY (CONTINUED)

ADDITIONAL CHANGES ARE NECESSARY AS A RESULT OF OPERATING PRESSURE DIFFERENCES

- BASELINE CHANGES (5 PSI ATMOSPHERE ;260 mmHg)
  - SKYLAB
    - NONE
  - SALYUT/SOYUZ
    - MODIFY ECS
      - CHANGE ATMOSPHERE CONTROL
      - PROVIDE PREBREATHE CAPABILITY
    - UPRATE THERMAL CONTROL SYSTEM
    - IMPROVE FIREPROOFING
- ALTERNATE I CHANGES (15 PSI ATMOSPHERE ;760 mmHg)
  - SKYLAB
    - ADAPT AIRLOCK MODULE STRUCTURE FOR HIGHER PRESSURE
    - ADD MULTIPLE DOCKING ADAPTER / CSM WITH PREBREATHE CAPABILITY
    - UPRATE ECS
      - ADD CSM PRESSURE MONITOR
      - CHANGE 2 GAS CONTROL SYSTEM
      - ADD 2 N_2 TANKS
      - UPRATE GAS SYSTEM TO 4500 PSI
  - SALYUT/SOYUZ
    - NONE
- ALTERNATE 2 CHANGES (8 PSI ATMOSPHERE ;414 mmHg)
  - SKYLAB
    - UPRATE ECS
      - CHANGE 2 GAS CONTROL SYSTEM
  - SALYUT/SOYUZ
    - MODIFY ECS
      - CHANGE ATMOSPHERE CONTROL
    - UPRATE THERMAL CONTROL SYSTEM
    - IMPROVE FIREPROOFING

COOPERATIVE SPACE MISSION

REQUIRED CHANGES

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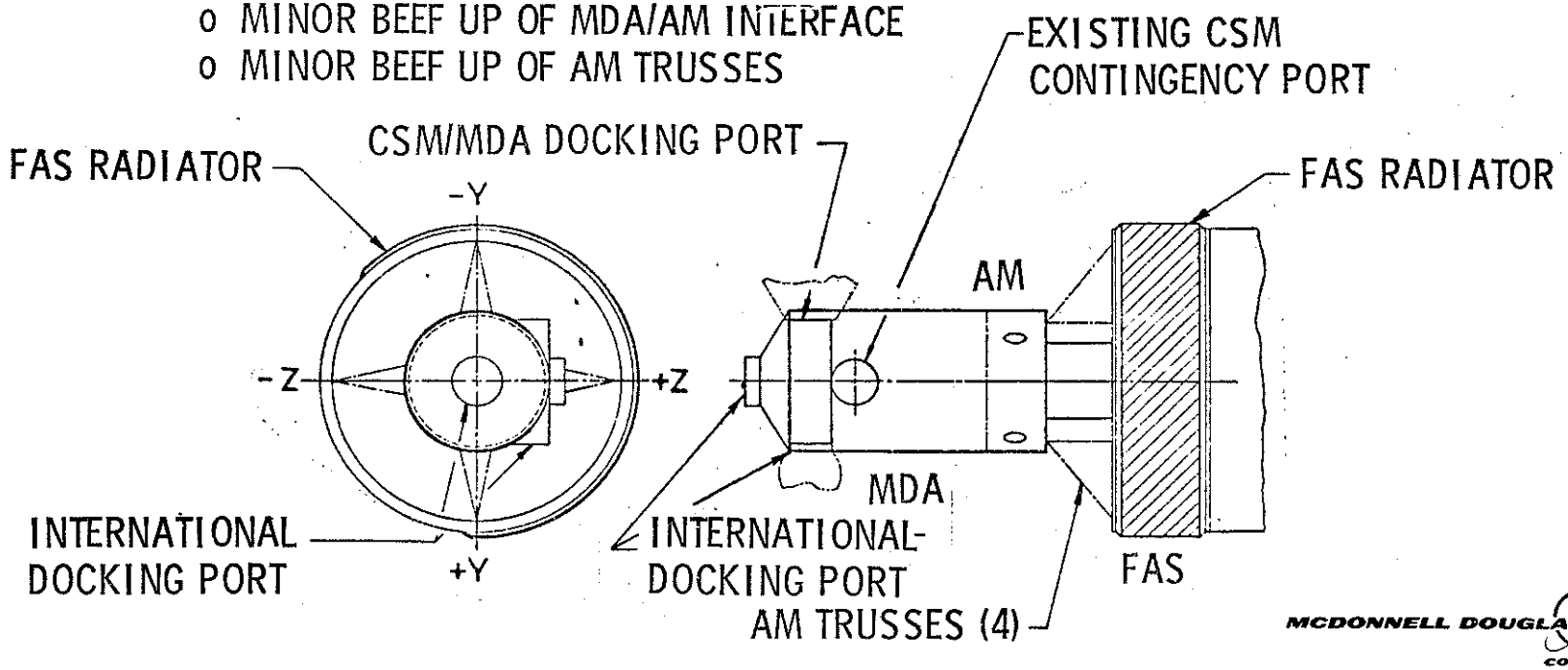
COOPERATIVE SPACE MISSION
STRUCTURE CHANGES

- o REQUIRED
  - o MULTIPLE DOCKING ADAPTOR (MDA)
    - o DISCONNECT RADIATOR
    - o CONVERT AXIAL CSM DOCKING PORT TO INTERNATIONAL DOCKING PORT
    - o ADD 2 RADIAL DOCKING PORTS
      - o 1 INTERNATIONAL
      - o 1 CSM
  - o FIXED AIRLOCK SHROUD (FAS)
    - o ADD RADIATOR
  - o AIRLOCK MODULE (AM)
    - o ALLOW FOR HIGHER DOCKING LOADS
      - o MINOR BEEF UP OF MDA/AM INTERFACE
      - o MINOR BEEF UP OF AM TRUSSES



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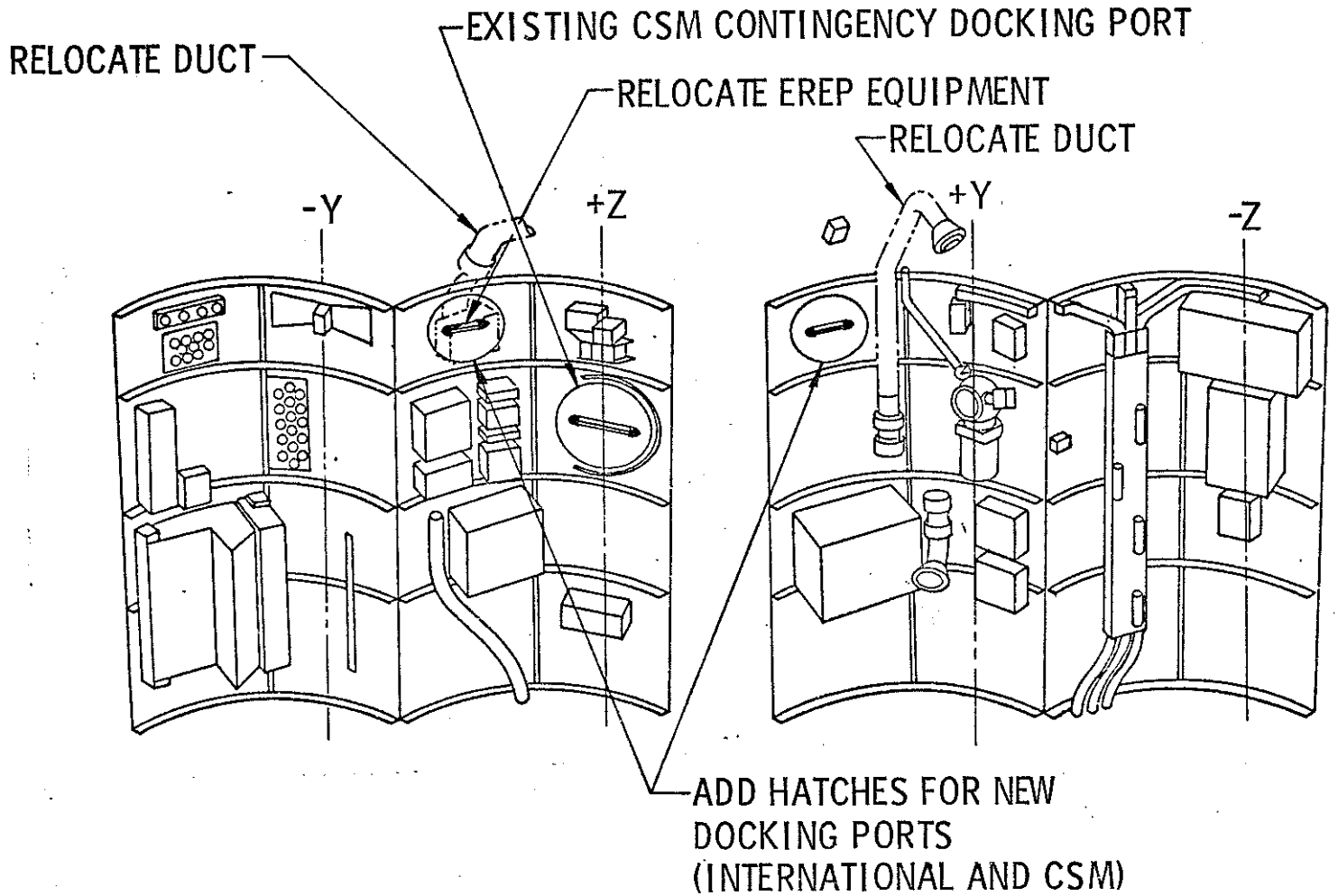
COOPERATIVE SPACE MISSION
MDA DOCKING PORTS



MDA INTERIOR STRETCH-OUT

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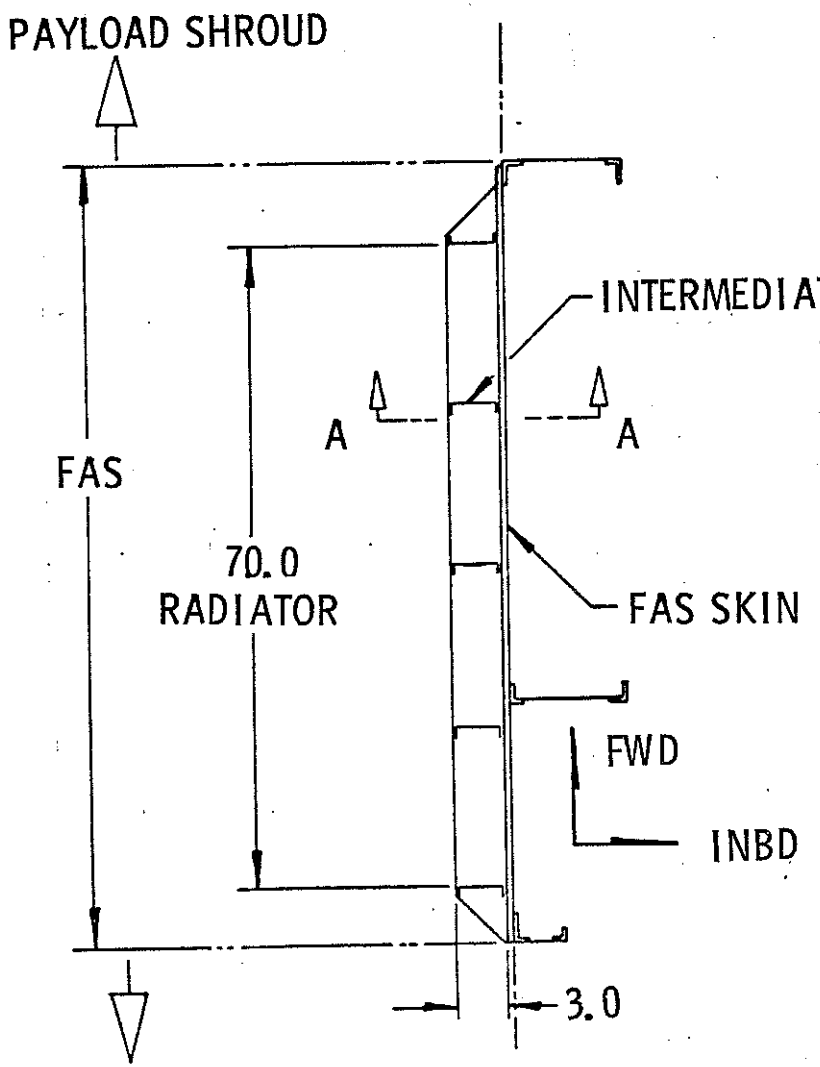
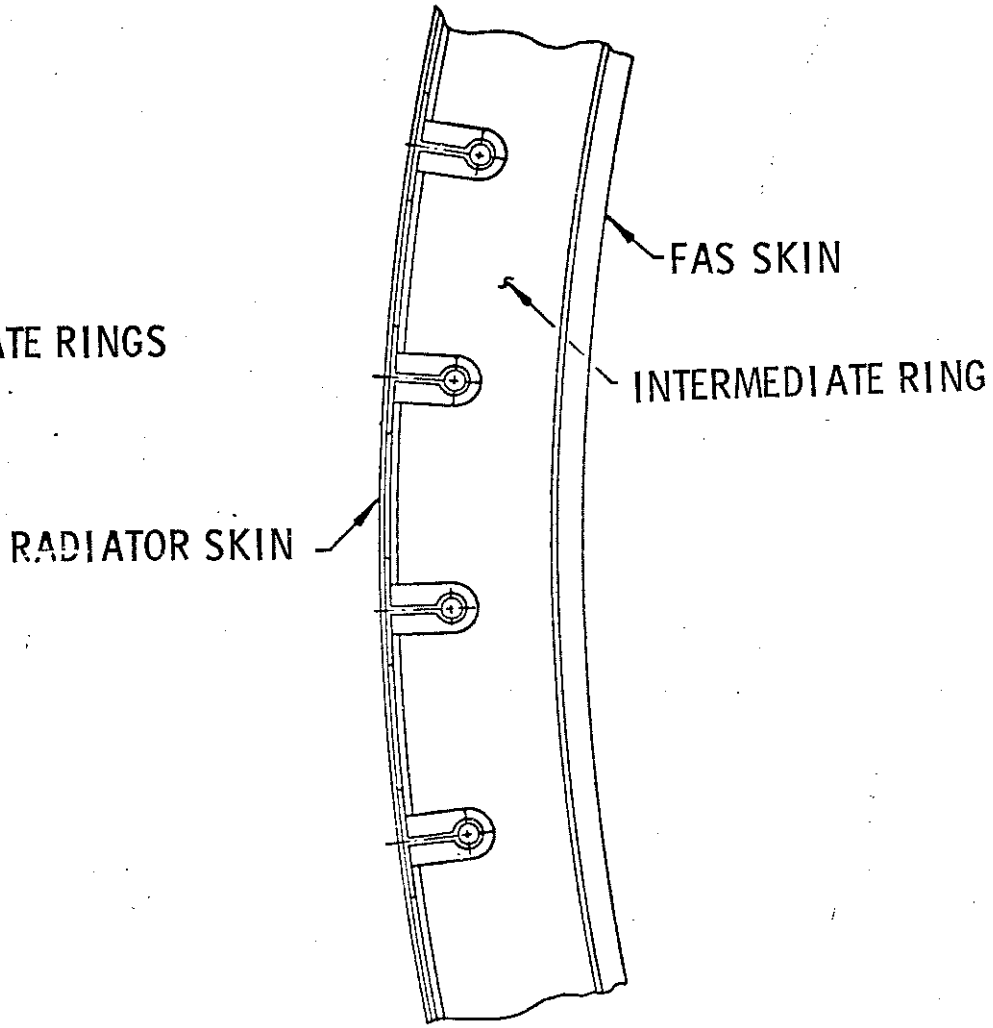
COOPERATIVE SPACE MISSION
FAS RADIATOR INSTALLATION



TYPICAL CROSS SECTION



A-A

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COOPERATIVE SPACE MISSION
ATTITUDE CONTROL CHANGES

SOLAR INERTIAL ATTITUDE MOMENTUM REQUIREMENT

- o 6025 FT·LB·SEC OF MOMENTUM REQUIRED TO COMPENSATE FOR GRAVITY GRADIENT TORQUES
  - o NO DEVIATION FROM SOLAR INERTIAL EXCEPT FOR DESATURATION
  - o NO VENTING OR OTHER DISTURBANCES ARE CONSIDERED
  - o MASS PROPERTIES BASED ON SKYLAB A DATA AND MINUTES OF DEC. 6, 1971 US/USSR AGREEMENT
- o CONTROL IS REQUIRED WITH 2 OUT OF 3 CONTROL MOMENT GYROS (CMG) OPERATING FOR NOMINAL SOLAR INERTIAL OPERATION

SKYLAB CMG SYSTEM MOMENTUM CAPACITY

- o 4600 FT·LB·SEC WITH 2 CMG'S OPERATING
- o 6900 FT·LB·SEC WITH 3 CMG'S OPERATING

CONCLUSION:

- o AN INCREASE OF 30% IS REQUIRED IN THE ANGULAR MOMENTUM OF THE SKYLAB A CMG SYSTEM TO MEET 2 OUT OF 3 CMG CONTROL CRITERIA

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
POTENTIAL MODIFICATIONS TO INCREASE MOMENTUM

MODIFY CMG'S

- o INCREASE MOMENTUM 30% TO 3000 FT·LB·SEC PER CMG
- o CMG DESIGNATED AS 2000 H WILL PROVIDE ADEQUATE MOMENTUM
  - o DESIGN IS COMPLETE AND PROTOTYPE HAS BEEN CONSTRUCTED

REPLACE SKYLAB A CMG'S WITH IMPROVED 2000 H CMG'S

- o IMPROVED 2000 H CMG CHARACTERISTICS
  - o 3000 FT·LB·SEC PER CMG (6000 WITH 2 CMG'S)
  - o UNLIMITED GIMBAL FREEDOM (IMPROVED EARTH RESOURCES VIEWING OPERATION BY REDUCING TACS CONSUMPTION PREVIOUSLY REQD TO AVOID GIMBAL STOPS)
  - o WEIGHT OF 2000 H CMG SAME AS SKYLAB A CMG - 420 LB.
  - o VOLUME OF 2000 H CMG SLIGHTLY LESS THAN SKYLAB A CMG - 18 FT^3
  - o MOUNTING FOR THE 2000 H CMG SAME AS SKYLAB A CMG
  - o 2000 H CMG REQUIRES DIFFERENT POWER SUPPLY AND SUPPORT ELECTRONICS THAN THE SKYLAB A UNIT
  - o PROTOTYPE UNIT TO BE TESTED LATER THIS YEAR AT MSFC.

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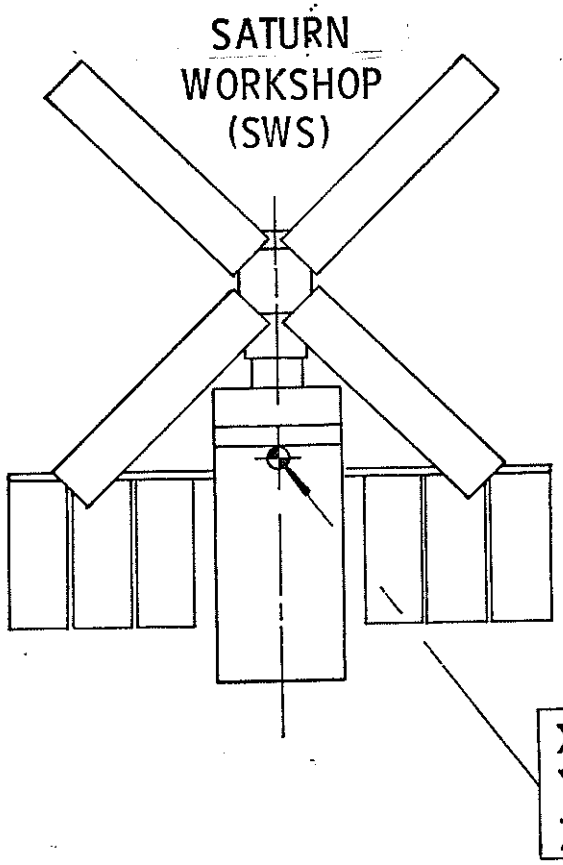
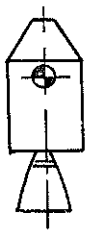
COOPERATIVE SPACE MISSION
VEHICLE MASS PROPERTIES



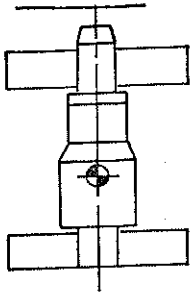
COORDINATES ARE RELATIVE TO DOCKING INTERFACES (FT.)

CSM



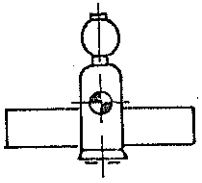
X = 11.81
Y = 0.06
Z = 0.28

SALYUT



X = 29.5
Y = 0.0
Z = 0.0

SOYUZ



X = 14.4
Y = 0.0
Z = 0.0

	SWS *	CSM *	SALYUT **	SOYUZ **
WEIGHT (LBS X 10^3)	164.8	28.3	41.9	14.3
INERTIA (SLUG FT^2 X 10^3)				
Ix	720.9	16.2	36.8	2.94
Iy	2799.	48.05	206.	14.7
Iz	2740.	48.32	198.5	14.7

* SKYLAB OPERATIONAL DATA BOOK, MSC-01549 VOL II REV A AMEND 2. SLI/2 @ DOCKING

** MINUTES OF 3RD USSR ACADEMY OF SCIENCES AND US NASA MEETING, NOV 29-DEC 6, 1971

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
CMG CONTROL CONSIDERATIONS

	SWS	SWS/CSM	SWS/CSM/SALYUT	SWS/CSM/SALYUT/SOYUZ
WEIGHT (LBM)	164, 800	193, 100	235, 000	249, 300
C.G. COORDINATES RELATIVE TO Y - Z AXES (FT)				
$X_{VEHICLE}$	-26. 6	-22. 2	-11. 44	-10. 57
$Y_{VEHICLE}$	0. 14	2. 57	2. 11	0. 88
$Z_{VEHICLE}$	2. 56	1. 62	1. 33	1. 03
INERTIA (SLUG-FT)				
I_{XV}	720, 900	1, 003, 300	1. 052, 000	1, 269, 000
I_{YV}	2, 799, 000	3, 526, 700	7, 800, 000	7, 750, 000
I_{ZV}	2, 740, 000	3, 372, 800	7, 776, 000	8. 090. 000
H_{TMAX}* (FT-LB-SEC)	1710	2285	5720 **	6025 **

* CMG DESIGN REQUIREMENT

** EXCEEDS SKYLAB A 2 OUT OF 3 CMG CRITERIA

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
SOYUZ/SALYUT ORBIT MANEUVER REQUIREMENTS

SOYUZ RENDEZVOUS AND DOCK WITH SALYUT

- 172 fps ΔV REQUIRED
  - 72 fps - ORBIT ENERGY INCREASE FROM 110 TO 130 n. m.
  - 90 fps - RENDEZVOUS DISPERSIONS & CONTINGENCY
  - 10 fps - DOCKING

SOYUZ/SALYUT RENDEZVOUS WITH SKYLAB (SALYUT PROPULSION)

- 457 fps ΔV REQUIRED
  - 367 fps - ORBIT ENERGY INCREASE FROM 130 TO 235 n. m.
  - 90 fps - RENDEZVOUS DISPERSIONS & CONTINGENCY

SOYUZ DOCK WITH SKYLAB

- 10 fps REQUIRED

SALYUT DOCK WITH SKYLAB

- 10 fps REQUIRED

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
SOYUZ MANEUVER SUMMARY

- SOYUZ HAS ADEQUATE MANEUVER CAPABILITY
  - SOYUZ MANEUVER REQUIREMENT
    - 182 fps ΔV TOTAL REQUIREMENT
      - 172 - RENDEZVOUS & DOCK WITH SALYUT
      - 10 - DOCK WITH SKYLAB
  - SOYUZ MANEUVER CAPABILITY
    - "IT IS WORTH NOTING THAT THE POTENTIALITIES OF THE ENGINE INSTALLATION OF THE SOYUZ SHIP PERMITS THE PERFORMANCE OF MANEUVERS UP TO AN ALTITUDE OF 1300 KM." *
    - ΔV REQUIRED TO RAISE ORBIT TO 1300 KM FROM A NOMINAL INSERTION ORBIT OF 205 KM IS 1200 fps
    - THEREFORE SOYUZ HAS 1200 fps MANEUVER CAPABILITY

* REF: ON THE WAY TO ORBITAL STATIONS IN SPACE p. 6, TRANSLATED FROM THE KRASNAYA ZVEZDA, N69-13685, JOINT PUBLICATIONS RESEARCH SERVICE.

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
SALYUT MANEUVER SUMMARY

- SALYUT HAS ADEQUATE MANEUVER CAPABILITY TO PERFORM MISSION
  - SALYUT MANEUVER REQUIREMENT
    - 625 fps ΔV TOTAL MANEUVER REQUIREMENT
      - 615 fps $\left(457 \text{ fps} \times \frac{M_{SALYUT} + M_{SOYUZ}}{M_{SALYUT}}\right)$ IS SOYUZ/SALYUT REQUIREMENT TO RENDEZVOUS WITH SKYLAB
      - 10 fps - SALYUT DOCK WITH SKYLAB
  - SALYUT MANEUVER CAPABILITY
    - DATA IN PUBLISHED LITERATURE FOR SALYUT MISSION IN 1971 SHOWS AT LEAST 765 fps ΔV CAPABILITY AS SHOWN BELOW:

MANEUVER ΔV (fps)	DATE	INITIAL ORBIT (APOGEE X PERIGEE-N. M.)	POST MANEUVER ORBIT (APOGEE X PERIGEE-N. M.)	REMARKS
--	19 APRIL	120 X 108	------	INSERTION
160	26 APRIL	100 X 96	150 X 135	
65 M_{SALYUT}	8 JUNE	131 X 114	143 X 129	SALYUT/SOYUZ
65 M_{SALYUT}	9 JUNE	142 X 128	152 X 145	SALYUT/SOYUZ
74	30 JUNE	128 X 120	161 X 128	
229	17 AUG	104 X 96	171 X 156	
172	11 OCT	98 X 96	98 X 00 (EST)	RETROGRADE
765 fps TOTAL				

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COOPERATIVE SPACE MISSION
SALYUT DOCKING REQUIREMENTS

- THREE AXIS TRANSLATION MANEUVER CONTROL REQUIRED FOR DOCKING WITH THE PASSIVE SKYLAB
  - MINIMUM VELOCITY INCREMENT MUST BE LESS THAN 0.1 M/SEC (0.33 FT/SEC) LATERALLY, AND LESS THAN 0.3 M/SEC (1.0 FT/SEC) AXIALLY IN ORDER TO MEET US/USSR DOCKING CRITERIA
  - ADEQUACY OF PRESENT PROPULSION AND CONTROL SYSTEMS UNKNOWN

- THREE AXIS ATTITUDE HOLD AND MANEUVER CONTROL REQUIRED FOR DOCKING WITH THE SKYLAB IN THE SOLAR INERTIAL ATTITUDE
  - PRESENT SYSTEM PROBABLY ADEQUATE

- DOCKING CREW STATION IN THE SALYUT REQUIRED
  - MUST INCLUDE THE FOLLOWING
    - PILOT ORIENTATION TO COINCIDE WITH CONTROL AXES
    - TRANSLATION CONTROLLER
    - ATTITUDE CONTROLLER
    - VISUAL DISPLAY OR DEVICES FOR ATTITUDE & POSITION ALIGNMENT CUES.
  - ABOVE CAPABILITY MUST BE ADDED

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COOPERATIVE SPACE MISSION
ECS/TCS CHANGES

- PROBLEM AREAS
  - DOCKING CONFIGURATION RESULTS IN BLOCKAGE OF RADIATOR VIEW FACTOR TO SPACE THEREBY DECREASING HEAT REJECTION CAPABILITY
  - RADIAL PORT DOCKING INCREASES POTENTIAL FOR CONTAMINATION OF RADIATOR THERMAL CONTROL COATINGS
  - INTERFACE WITH TWO ADDITIONAL DOCKED VEHICLES WILL INCREASE TOTAL CLUSTER GAS LEAKAGE
- PROPOSED SOLUTIONS
  - INSTALL 260 FT^2 RADIATOR ON FIXED AIRLOCK SHROUD
  - DISCONNECT PLUMBING FROM MDA RADIATOR PANELS WHICH HAVE BEEN RENDERED INEFFECTIVE. RETAIN PANELS FOR METEOROID PROTECTION
  - INCREASE GAS STORAGE CAPABILITY
    - O_2 TANKS ARE DESIGNED TO OPERATE AT 4500 PSI VERSUS SL-A's 3000 PSI
  - OPERATE SALYUT PRESSURE CONTROL SYSTEM TO PROVIDE MAKEUP FOR SOYUZ/SALYUT GAS LOSSES OR CONSUMPTION

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
ECS/TCS CHANGES

- PROBLEM AREAS
  - POTENTIAL EXISTS FOR SIX CREWMEN IN SKYLAB THEREBY INCREASING LOCAL CONCENTRATIONS OF CO_2, MOISTURE, ODORS, AND SENSIBLE HEAT IN THE CLUSTER ATMOSPHERE
  - SKYLAB NORMAL OPERATING CONFIGURATION WILL NOT SUPPORT A SIX MAN CREW

- PROPOSED SOLUTION
  - SIMULTANEOUS OPERATION OF SALYUT AND SKYLAB ATMOSPHERIC CONTROL SYSTEMS
  - INSTALLATION OF INTERCHANGE DUCT AND FAN TO PROVIDE ADEQUATE CIRCULATION BETWEEN SKYLAB AND SALYUT. GAS INTERCHANGE WILL PREVENT UNDESIRABLE TEMPERATURE, HUMIDITY, AND CO_2 PARTIAL PRESSURE GRADIENTS AND PERMIT MAXIMUM UTILIZATION OF SYSTEMS CAPABILITIES OF EACH VEHICLE.

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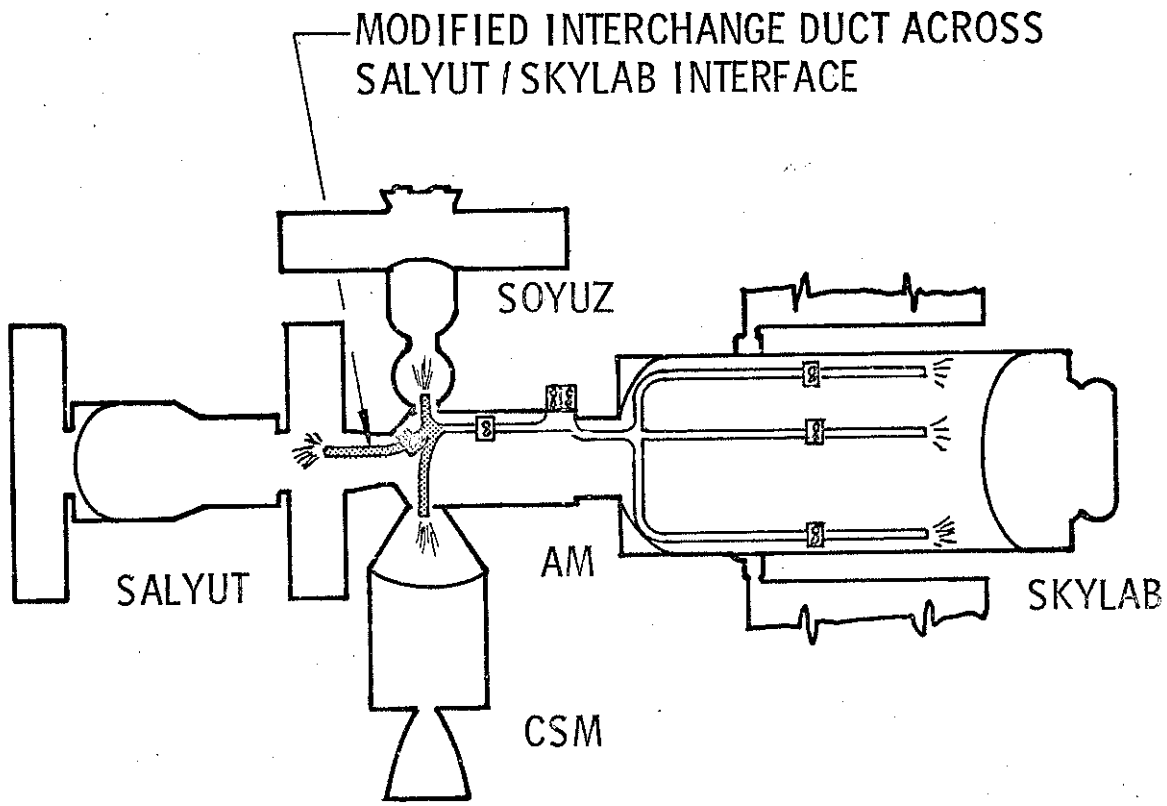
COOPERATIVE SPACE MISSION
ECS INTERCHANGE DUCT



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COOPERATIVE SPACE MISSION
ELECTRICAL POWER SYSTEM

- SKYLAB/CSM, SALYUT, AND SOYUZ ELECTRICAL SYSTEMS WILL BE ISOLATED AND INDEPENDENT
  - NO POWER TRANSFER FROM SKYLAB TO RUSSIAN VEHICLES
    - SKYLAB POWER MAY BE INCOMPATIBLE (E.G. DIFFERENT VOLTAGE)
- SHADOWING OF SALYUT SOLAR ARRAYS BY ATM RESULTS IN 25% REDUCTION OF SALYUT POWER AND ENERGY CAPABILITY
  - NET LOSS OF USEFUL POWER IS ESTIMATED AS LESS THAN 200 WATTS
  - USSR POWER SAVINGS FROM DEACTIVATION OF ATTITUDE CONTROL SYSTEM IS UNKNOWN
- NEW RADIAL DOCKING PORT OF MDA MUST BE WIRED FOR MDA/CSM ELECTRICAL INTERFACE
  - WIRING CAN BE REROUTED FROM AXIAL PORT TO NEW RADIAL PORT
- SKYLAB ELECTRICAL POWER CAPABILITY IS SAME AS FOR SKYLAB A
- IMPACT ON SKYLAB POWER CAUSED BY PARTIAL SHADOWING OF CSM IS NEGLIGIBLE

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COOPERATIVE SPACE MISSION
RENDEZVOUS AND DOCKING AIDS

- US/USSR AGREEMENT REQUIRES COMPATIBLE RENDEZVOUS AND DOCKING SYSTEMS
  - DEVELOP NEW COMMON RADIO GUIDANCE SYSTEM FOR RENDEZVOUS OPERATIONS IN 10 CM WAVEBAND FOR SKYLAB AND SOYUZ
  - ADD APOLLO VHF RANGING SYSTEM AS BACKUP TO SOYUZ
  - ADD STANDARDIZED DOCKING TARGET TO SKYLAB INTERNATIONAL DOCKING PORTS
  - COMPATIBILITY OF EXISTING FLASHING LIGHT BEACONS AND ORIENTATION LIGHTS IS TO BE DETERMINED

COOPERATIVE SPACE MISSION
ADDITION OF S-BAND TRANSMISSION SYSTEM

RATIONALE

- o US/USSR AGREEMENT REQUIRES RADIO GUIDANCE SYSTEM IN 10 CM BAND
  - o S-BAND COVERS 5.77 TO 19.3 CM BAND
- o VHF BANDWIDTH IS INADEQUATE FOR COOPERATIVE SPACE LABORATORY DATA QUANTITY
  - o ONLY 2 CSM'S TO RETURN HARD DATA
  - o EARTH SURVEY DATA REQUIRES 14.0 MHZ BANDWIDTH
  - o SKYLAB-A VHF HAS ONLY 125 KHZ BANDWIDTH
- o COMPATIBLE WITH ALL NASA AND AIR FORCE GROUND STATIONS AND COMMUNICATIONS SATELLITES
- o PROVIDE MORE ACCURATE RANGING CAPABILITY
- o ALLOWS RANGE RATE CAPABILITY

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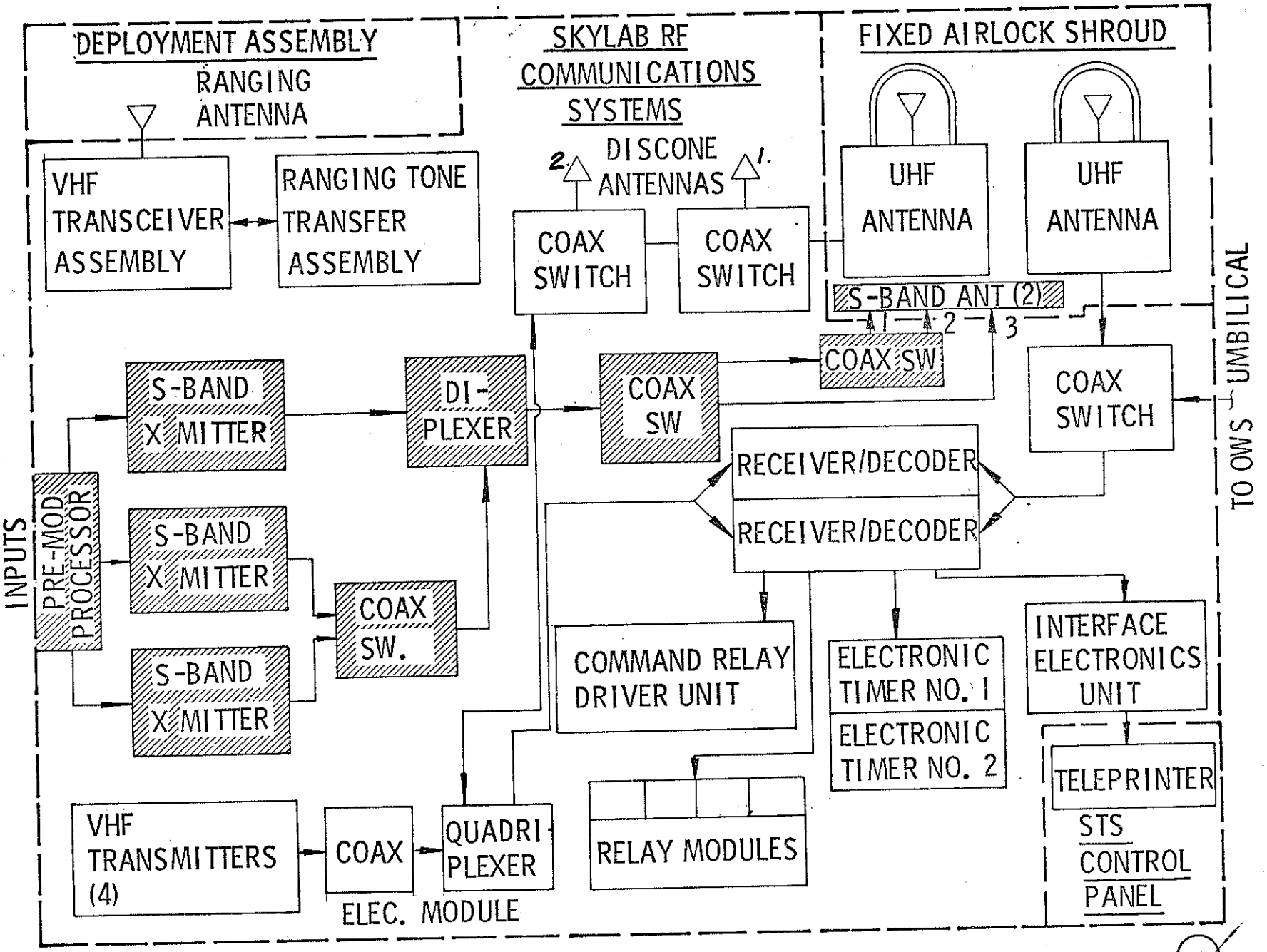
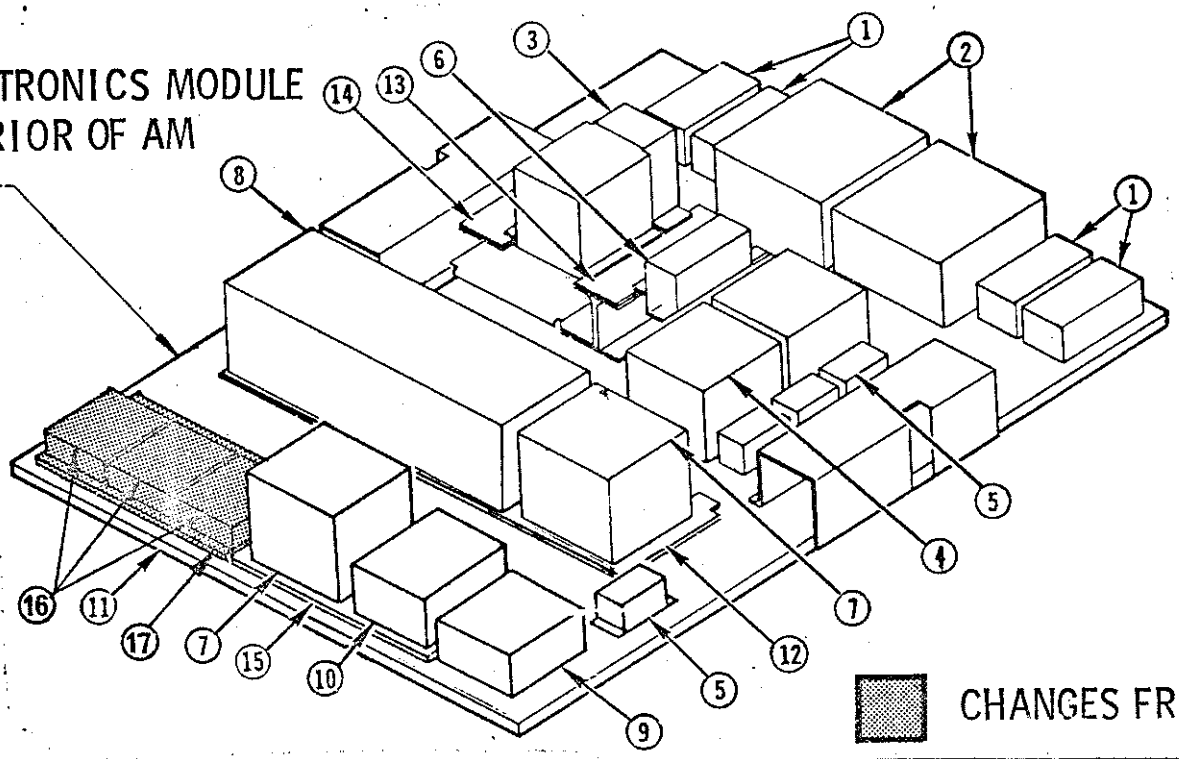


ADDED TO SKYLAB-A COMMUNICATION SYSTEM

COOPERATIVE SPACE MISSION
S-BAND XMITTERS INSTALLATION

EXISTING ELECTRONICS MODULE NO. 5 ON EXTERIOR OF AM TUNNEL SKIN



CHANGES FROM SKYLAB-A

KEY	QTY	PART NUMBER	PART NOMENCLATURE
1	4	61C880052	DC-DC CONVT. PNL MTR.
2	2	61A850004	AUDIO LOAD COMP
3	1	61C850006	VHF TRANSCEIVER
4	2	61B880054	HUMIDITY SENSING CTRL
5	4	61B880058	GAS FLOW METER
6	1	61C850005	RANGING TONE XFER ASSY
7	2	61A880000	INSTR. PKG.
8	1	61B850012	CAUTION & WARNING UNIT
9	1	61A762269	RLY.PNL. C&W
10	1	61B850012	HIGH LEVEL AUDIO AMPLIFIER

KEY	QTY	PART NUMBER	PART NOMENCLATURE
11	1	61A820043	PANEL ASSY
12	1	61A830257	C&W COLDPLATE ASSY
13	1	61A830199	RTTA COLDRAIL ASSY
14	1	61A830293	TRANSCEIVER COLDRAIL
15	1	61A830323	C&W NO. 2 COLD PLATE ASSY
16	3	----------	S-BAND TRANSCEIVER
17	1	----------	S-BAND COLDPLATE

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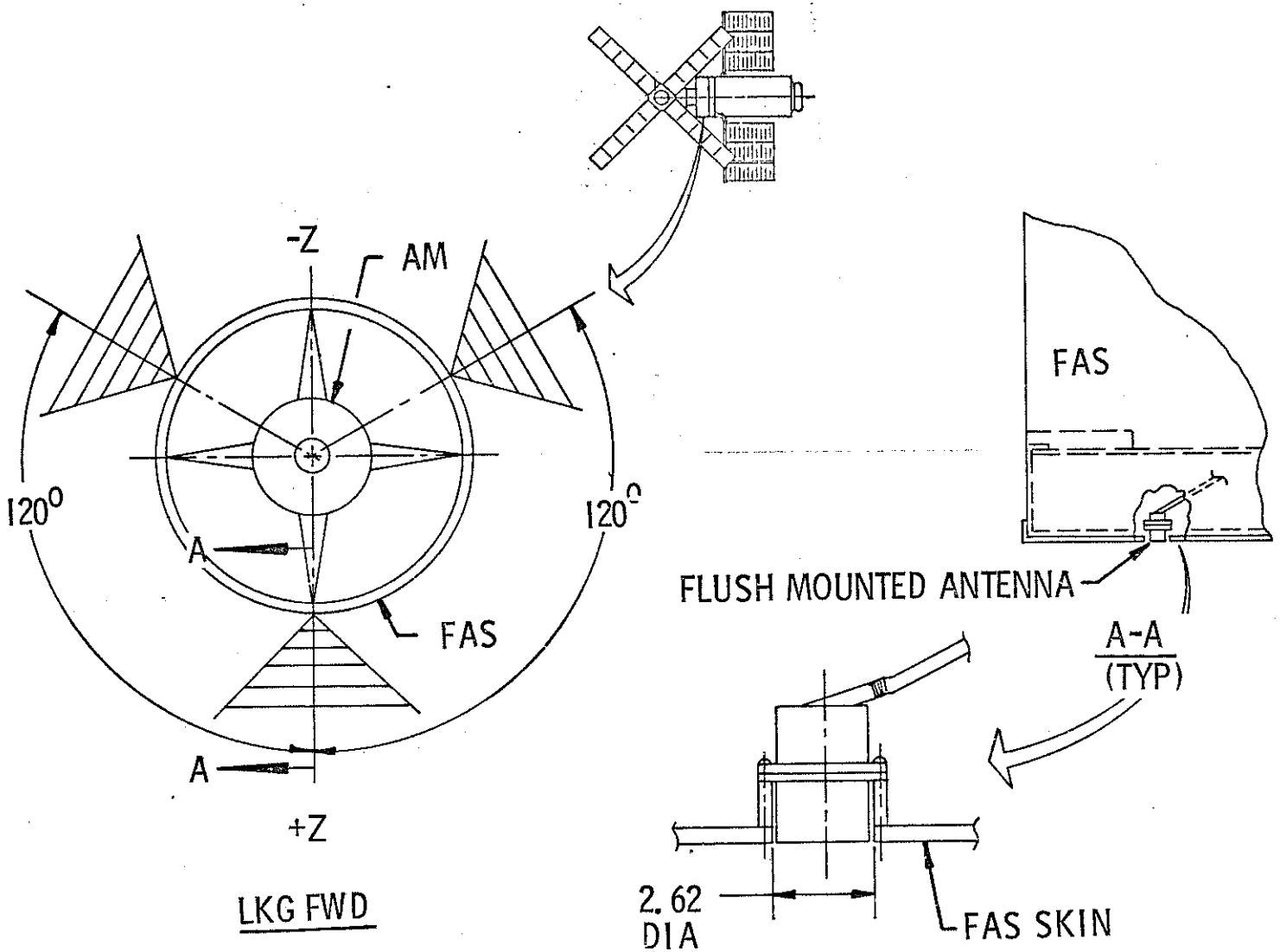
COOPERATIVE SPACE MISSION
S-BAND FLUSH MOUNTED ANTENNA



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COOPERATIVE SPACE MISSION
SKYLAB/SALYUT HARDLINE COMMUNICATIONS LINK

- ADD SKYLAB/SALYUT INTERFACE CABLES
- TWO CHANNELS EACH FOR
  - MICROPHONE
  - EARPHONE
  - SKYLAB CALL
  - SALYUT CALL
- ADD TWO AUDIO LOAD COMPENSATORS
- ADD 3-4 SWITCHING RELAYS

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION OPTION

BASELINE CHANGES (5 PSI)

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
SKYLAB BASELINE (5 PSI) CHANGES

- SKYLAB AND CSM ARE DESIGNED FOR 5 PSI OPERATIONS
  - US/USSR AGREEMENT CHANGES PARTIAL PRESSURE OF O_2
    - PPO_2 GOES FROM 3.7 PSIA TO 3.5 PSIA
    - PPN_2 GOES THEN GOES FROM 1.3 PSIA TO 1.5 PSIA
  - NO SKYLAB AND CSM CHANGES REQUIRED EXCEPT MINOR GAS SYSTEMS CHANGES

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION

BASELINE (5 PSI) O_2 AND N_2 CONSUMABLES

3 MEN-140 DAY MISSION AT 3.5 PSIA O_2 AND 1.5 PSIA N_2	GAS CONSUMABLES (LBS)			
	SPECIFICATION		NOMINAL*	
	O_2	N_2	O_2	N_2
METABOLIC O_2 (2.0 LB/MAN SKYLAB SPEC; 1.63 LB/MAN-DAY NOM *)	840	---	685	---
LEAKAGE (15.2 LB/DAY SPEC; 10.35 LB/DAY NOM *)	1635	490	1120	329
MOLECULAR SIEVE (3.48 LB/DAY SPEC; 2.79 LB/DAY NOM *)	352	135	282	108
AM AND MDA PRESSURIZATION (1764 FT^3 AT 40°F)	37	9	37	9
OWS PRESSURIZATION (9550 FT^3 AT 40°F)	198	46	198	46
EVA LOCK REPRESS (276 FT^3 AT 50°F WITH 6 REPRESS CYCLES)	34	8	34	8
EVA PREBREATHING AND EVA O_2 (2.8 LB/MAN-HR)	140	---	140	---
EXPERIMENTS	119	42	119	42
OWS DRINKING WATER TANK PRESSURIZATION	---	28	---	28
LEAKAGE FROM O_2 AND N_2 SUPPLY TANKS AND SYSTEM	11	5	11	5
TOTAL	3366	763	2626	575

* BASED ON SKYLAB A TEST DATA

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
BASELINE (5 PSI) LEAKAGE DERIVATION

	FLOW RATE (LB/DAY)			
	SPECIFICATION	TEST RESULTS	NOMINAL	REMARKS
LEAKAGE SOURCE	5 PSIA	5 PSID	5 PSIA	
CSM	2.4	---	2.4	
SALYUT/MDA INTERFACE	(1.2)	---	(1.2)	LEAKAGE CHARGED TO SALYUT
CSM/SOYUZ/MDA INTERFACE	2.4	---	2.4	BASED ON CSM/MDA I/F DATA
MDA DOCKING PORT	.2	---	.2	MDA HATCH CLOSED
MDA AND AM	5.2	2.0	3.0	
OWS	5.0	1.1 *	2.35	LEAKAGE + 50% + TRASH AIRLOCK
TOTALS	15.2	---	10.35	

* LEAKAGE ONLY

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
BASELINE (5 PSI) O_2 AND N_2 QUANTITIES

	O_2	N_2
CAPACITY AT 3000 PSIA AND 100°F (LBS)	5611	1511
RESIDUAL AT 300 PSIA AND 0°F (LBS)	681	191
USABLE AT NORMAL FLOW RATES (LBS)	4930	1320
COMSUMABLES REQUIRED* (LBS)	2626	575
MARGIN (LBS)	2304	745

* BASED ON NOMINAL VALUES DERIVED FROM TEST DATA

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
USSR BASELINE (5 PSI) CHANGES

- SALYUT/SOYUZ CHANGES
  - UPRATE THERMAL CONTROL SYSTEM
    - CONVECTIVE HEAT TRANSFER REDUCED AT 5 PSI
  - REVISE TWO-GAS CONTROL SYSTEM
  - ADD 0_2 MASKS FOR PREBREATHING
  - VERIFY $C0_2$ REMOVAL SYSTEM AND HUMIDITY CONTROL OPERATION AT 5 PSI
  - VERIFY NO EXCESSIVE ΔP IN PRESSURIZED SYSTEMS
  - REVISE CONTROLS AND DISPLAYS FOR TWO PRESSURE SYSTEM
  - REVISE C&W FOR TWO PRESSURE SYSTEM AND FOR GREATER FIRE MONITORING
  - REPLACE ALL MATERIALS WITH HIGH FLAME RATE AT 5 PSI WITH FIRE RETARDANT MATERIALS

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION

OPTION

ALTERNATE I CHANGES (15 PSI)

MCDONNELL DOUGLAS CORPORATION

STRUCTURE CHANGES FOR ALTERNATE I (15 PSI)

- AIRLOCK MODULE - TUNNEL SECTION
  - MAJOR MODIFICATION
    - INTERNAL BULKHEADS (3)
    - INTERNAL HATCHES (2)
    - FLEXIBLE TUNNEL EXTENSION
    - EVA HATCH TORQUE BOX
    - EVA HATCH LATCHES
  - MINOR BEEF-UP
    - ECS HOUSING
    - EVA HATCH
    - RADIAL SHEAR WEB ASSEMBLIES
    - TUNNEL SKIN
    - STRINGERS
    - INTER-COMPARTMENT DUCTS
    - EVA HATCH WINDOW
    - SUPPORT TRUSSES
- AIRLOCK MODULE - STRUCTURE TRANSITION SECTION
  - MAJOR MODIFICATION
    - STS/MDA INTERFACE
    - INTERCOSTALS
    - RINGS
    - BULKHEAD
    - PRESSURE SKIN
    - WINDOW DESIGN
  - MINOR BEEF-UP
    - WINDOW SUPPORT FRAMES
- MULTIPLE DOCKING ADAPTER
  - ADD
    - CSM/MDA AIRLOCK AT RADIAL CSM DOCKING PORT

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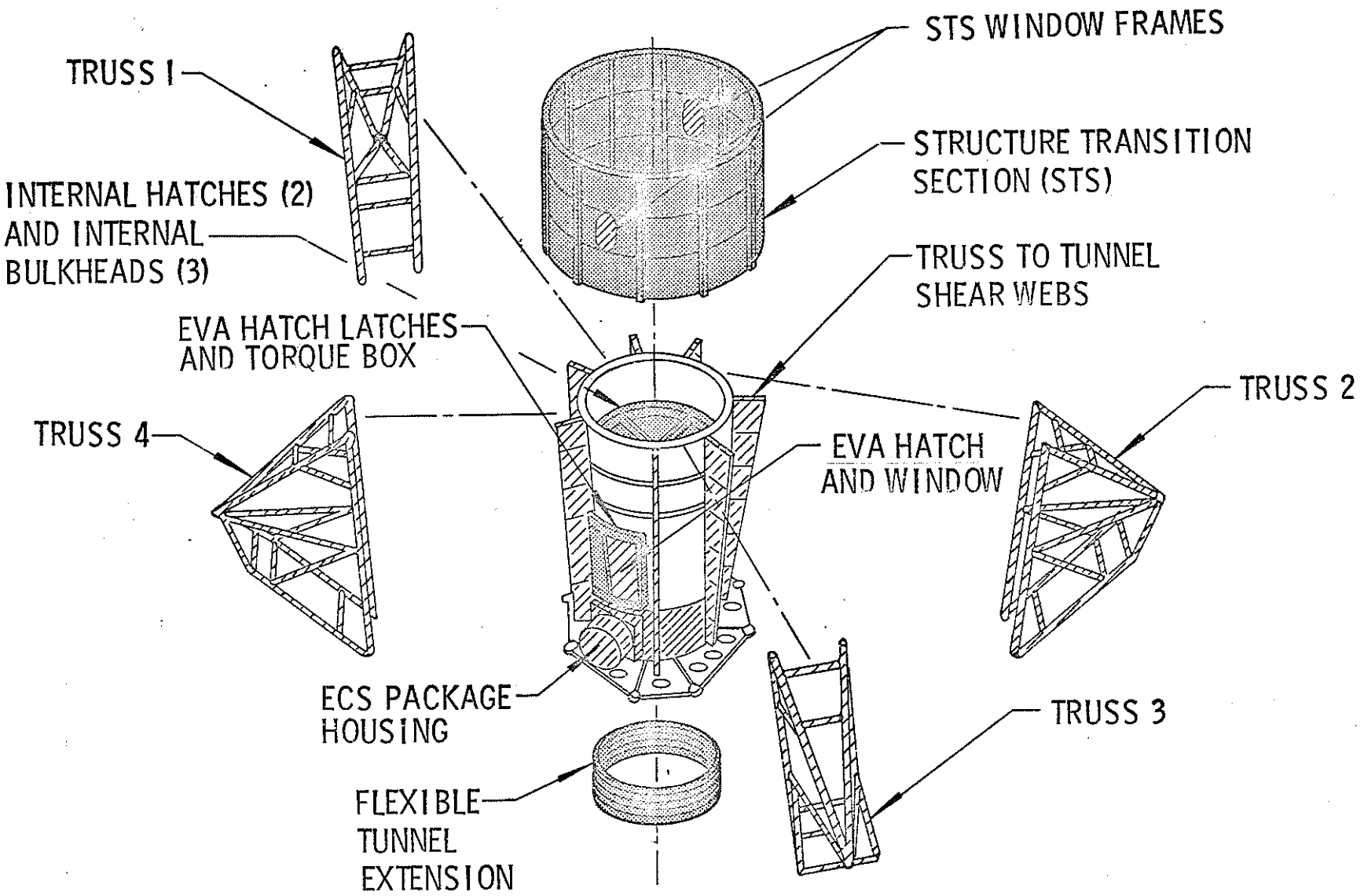
COOPERATIVE SPACE MISSION
AM STRUCTURE CHANGES
ALTERNATE I (15 PSI)



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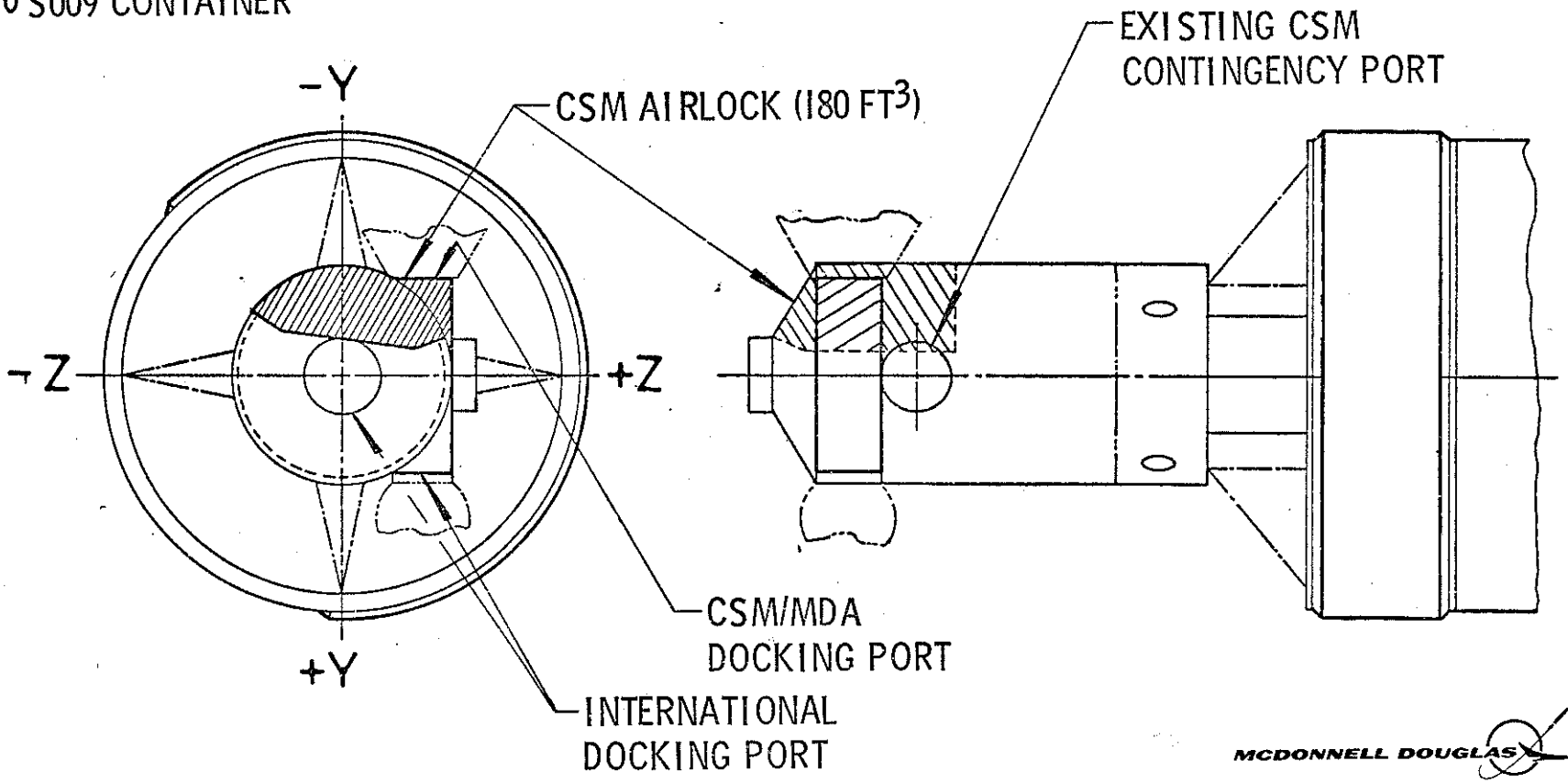
COOPERATIVE SPACE MISSION
ADDITION OF CSM/MDA AIRLOCK
ALTERNATE I (15 PSI)

MDA EQUIPMENT TO BE RELOCATED:

- EREP RACK NO. 2
  - S192 ELECTRONICS
  - EREP TAPE RECORDERS
  - EREP C & D PANEL
  - S190 STOWAGE CONTAINER
- ATM ELECTRICAL CONNECTORS
- S009 CONTAINER



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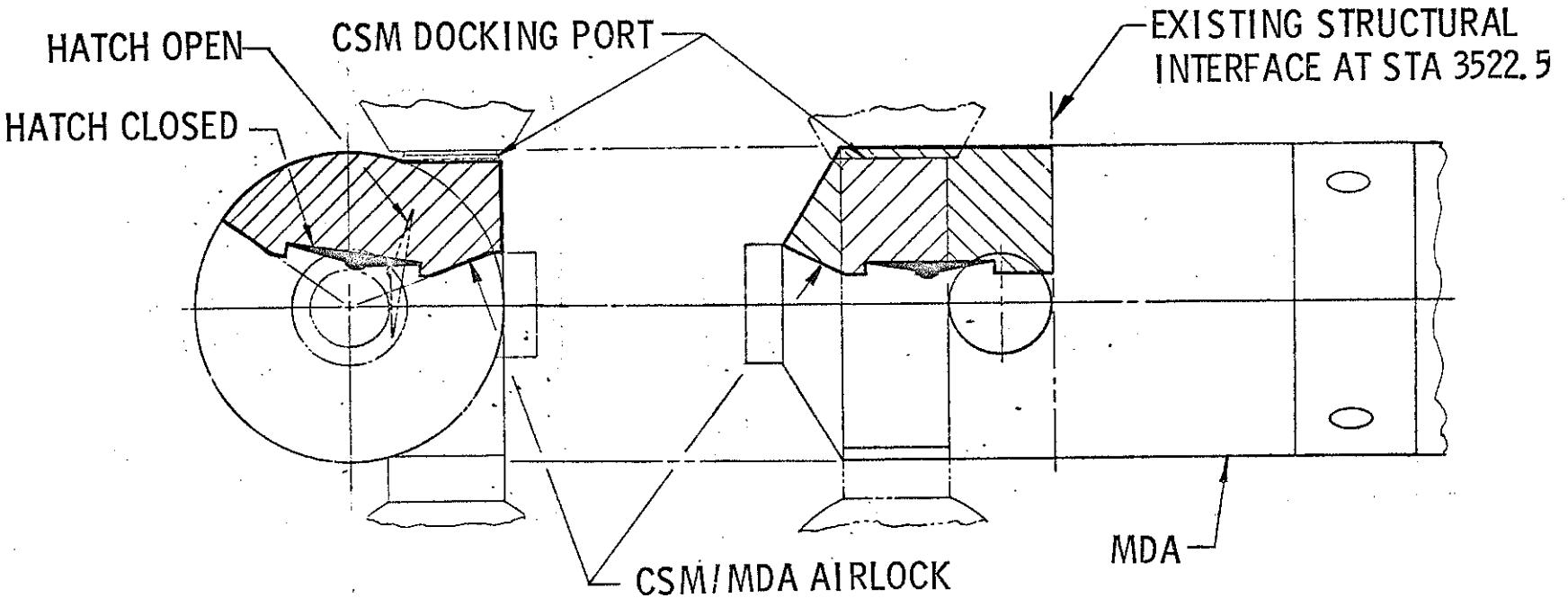
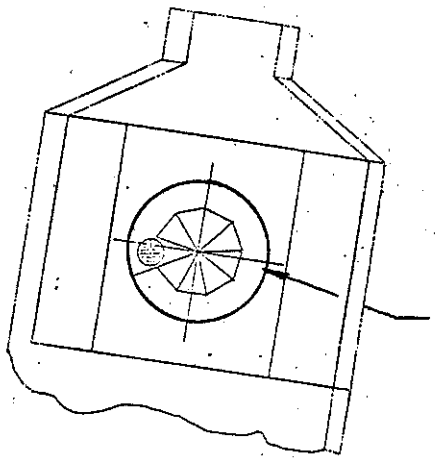
CORPORATION

COOPERATIVE SPACE MISSION

CSM/MDA AIRLOCK





SKYLAB INTERNAL HATCH AND MECHANISM

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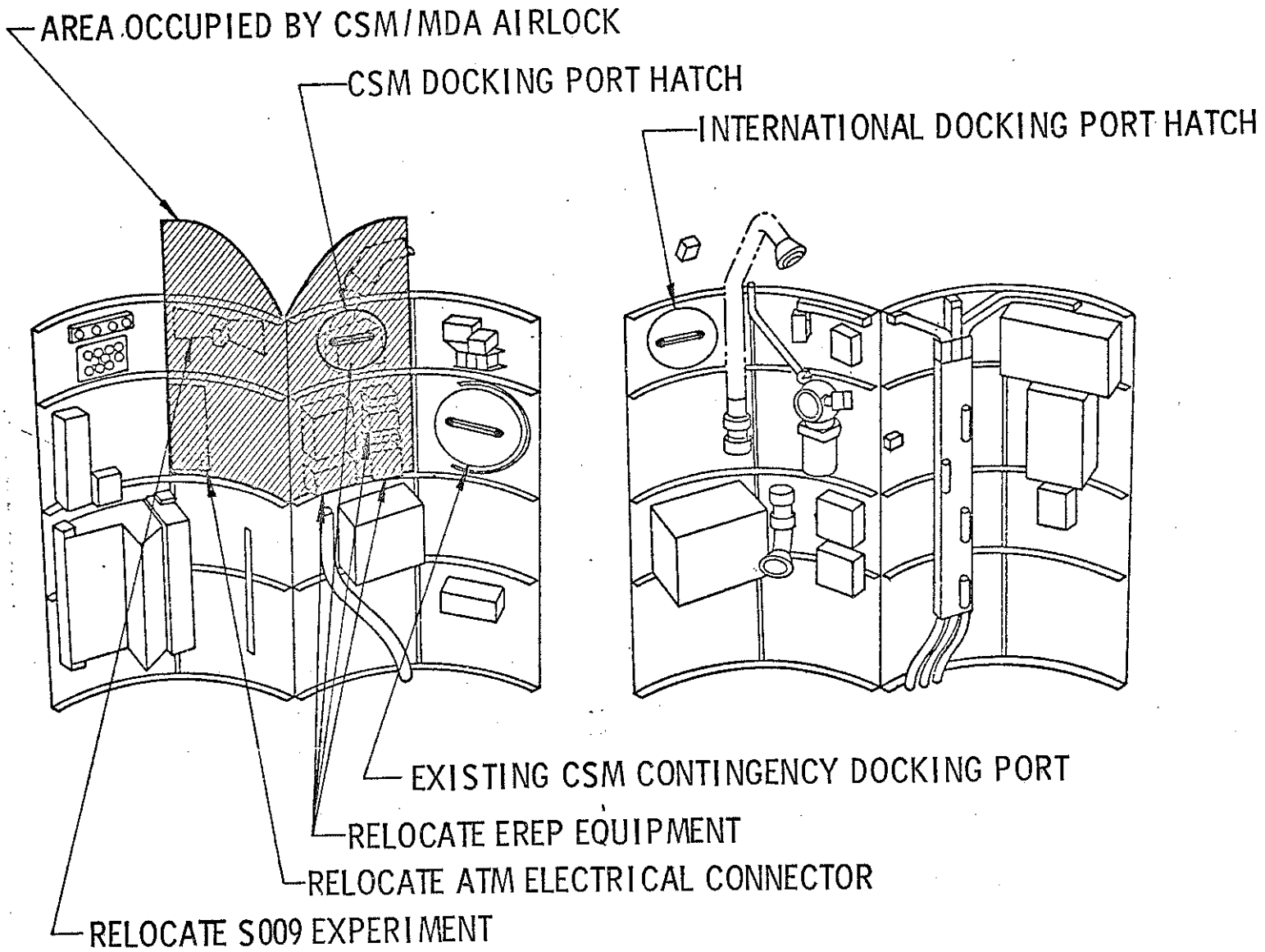
COOPERATIVE SPACE MISSION
CSM/MDA AIRLOCK


AREA OCCUPIED BY CSM/MDA AIRLOCK
CSM DOCKING PORT HATCH
INTERNATIONAL DOCKING PORT HATCH
EXISTING CSM CONTINGENCY DOCKING PORT
RELOCATE EREP EQUIPMENT
RELOCATE ATM ELECTRICAL CONNECTOR
RELOCATE S009 EXPERIMENT

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
ALTERNATE I (15 PSI) ECS/TCS CHANGES

- PROBLEM AREAS
  - SKYLAB PRESSURE MUST BE CONTROLLED TO 14.7 PSIA NOMINAL
  - CSM CANNOT WITHSTAND 14.7 PSIA INTERNAL PRESSURE AND MUST BE ISOLATED FROM REMAINDER OF CLUSTER
  - HIGHER INTERNAL PRESSURE SIGNIFICANTLY INCREASES CLUSTER OVERBOARD LEAKAGE RATES
  - O_2 PRE-BREATHING REQUIRED PRIOR TO EVA OR TRANSFER TO 5 PSIA CSM

- PROPOSED SOLUTIONS
  - NEW REGULATORS AND CABIN PRESSURE RELIEF VALVES REQUIRED TO PROVIDE 14.7 PSIA ATMOSPHERE
  - CONTROL AND DISPLAY RANGE CHANGES ARE REQUIRED FOR CABIN AND REGULATED PRESSURES
  - MODIFY VALVES, REGULATORS AND PRESSURE TRANSDUCERS FOR 4500 PSI

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
ALTERNATE I (15 PSI) ECS/TCS CHANGES (CONTINUED)

- PROPOSED SOLUTIONS (CONTINUED)
  - ADDITIONAL VALVING FOR 5 PSIA PRESSURE SOURCE WILL BE REQUIRED TO PREVENT EXCESSIVE ΔP ACROSS CONDENSING HEAT EXCHANGER WATER SEPARATOR PLATES
    - PRESENT DESIGN PREVENTS GAS LOSS FROM CABIN AT A ΔP UP TO APPROXIMATELY 13 PSI (BASED ON TEST DATA)
  - NEW CONDENSATE TANK WITH THICKER WALL REQUIRED
    - ULTIMATE COLLAPSING PRESSURE IS 10.9 PSID
  - NEW LOCK COMPARTMENT REQUIRED TO PERMIT TRANSFER TO 5 PSIA CSM
    - LOCK MUST PROVIDE O_2 SUPPLY, COOLING CAPABILITY, CONTROLS AND DISPLAYS
  - O_2 MASKS ARE NECESSARY FOR PRE-BREATHING OPERATION
  - FOR THE PRESENT 140 DAY MANNED MISSION, NITROGEN REQUIREMENTS ARE SIGNIFICANTLY INCREASED
    - USE RATE OF ATMOSPHERIC GAS DUE TO LEAKAGE AND OVERBOARD DUMP IS PROPORTIONAL TO PARTIAL PRESSURE OF THE GAS
      - OXYGEN PARTIAL PRESSURE IS REDUCED SLIGHTLY (FROM 3.7 TO 3.5 PSIA)
      - NITROGEN PARTIAL PRESSURE INCREASES BY ALMOST AN ORDER OF MAGNITUDE (FROM 1.3 TO 11.2 PSIA)
    - APPROXIMATELY 3100 POUNDS OF ADDITIONAL NITROGEN IS REQUIRED FOR THE FULL MISSION
      - 2 ADDITIONAL NITROGEN TANKS ARE REQUIRED

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
ALTERNATE I (15 PSI) O_2 N_2 CONSUMABLES

3 MEN-140 DAY MISSION AT 3.5 PSIA O_2, 11.2 PSIA N_2	GAS CONSUMABLES - LBS			
	SPECIFICATION		NOMINAL *	
	O_2	N_2	O_2	N_2
METABOLIC O_2 (2.0 LB/MAN-DAY SPEC; 1.63 LB/MAN-DAY NOMINAL)*	840	---	685	---
LEAKAGE (34.7 LB/DAY SPEC; 20.4 LB/DAY NOMINAL)*	1274	3585	749	2103
MOLECULAR SIEVE (10.2 LB/DAY DESIGN; 8.2 LB/DAY NOMINAL)*	378	1050	308	840
AM & MDA PRESSURIZATION (1764 FT^3 AT 40°F)	37	96	37	96
OWS PRESSURIZATION (9550 FT^3 AT 40°F)	198	516	198	516
EVA LOCK REPRESSURIZATION (276 FT^3 AT 50°F WITH 6 REPRESS CYCLES	34	95	34	95
EVA PREBREATHING & EVA O_2 (PREBREATHING - 1.9 LB/MAN-HR; EVA - 9.0 LB/MAN-HR)	140	---	140	---
EXPERIMENTS	119	329	119	329
OWS DRINKING WATER TANK PRESSURIZATION	---	35	---	35
LEAKAGE FROM O_2 & N_2 SUPPLY TANKS & SYSTEM	9	15	9	15
CSM VISITS (ONCE PER WEEK, REPRESS MDA LOCK (180 FT^3, 14.7 PSIA) & CSM (320 FT^3, 5 PSIA PREBREATH 1.9 LB/H OF O_2 FOR 3 HOURS)	356	206	356	206
TOTALS	3385	5927	2635	4235

* BASED ON SKYLAB A TEST DATA

COOPERATIVE SPACE MISSION
ALTERNATE I (15 PSI) LEAKAGE DERIVATION

	FLOW RATE (LB/DAY)			
	SPECIFICATION	TEST RESULTS	NOMINAL	REMARKS
LEAKAGE SOURCE	14.7 PSIA*	5 PSID	14.7 PSIA*	
SOYUZ/MDA INTERFACE	3.53	---	3.53	BASED ON CSM/MDA I/F DATA
SALYUT/MDA INTERFACE	(3.53)	---	(3.53)	LEAKAGE CHARGED TO SALYUT
MDA DOCKING PORTS(2)	1.18	---	1.18	CSM/MDA HATCH CLOSED (CSM ISOLATED**)
MDA AND AM	15.3	2.0	8.76	
OWS	14.7	1.1***	6.91	LEAKAGE + 50% + TRASH AIRLOCK
TOTALS	34.7	---	20.4	

*LEAKAGE ASSUMED TO INCREASE LINEARLY WITH PRESSURE (BASED ON ORIFICE CHOKE FLOW THEORY)

** CSM LEAKAGE CHARGED TO CSM; CSM ALLOWED TO DECAY, MDA/AL DUMPED INTO CSM ON WEEKLY VISIT

*** LEAKAGE ONLY

MCDONNELL DOUGLAS CORPORATION

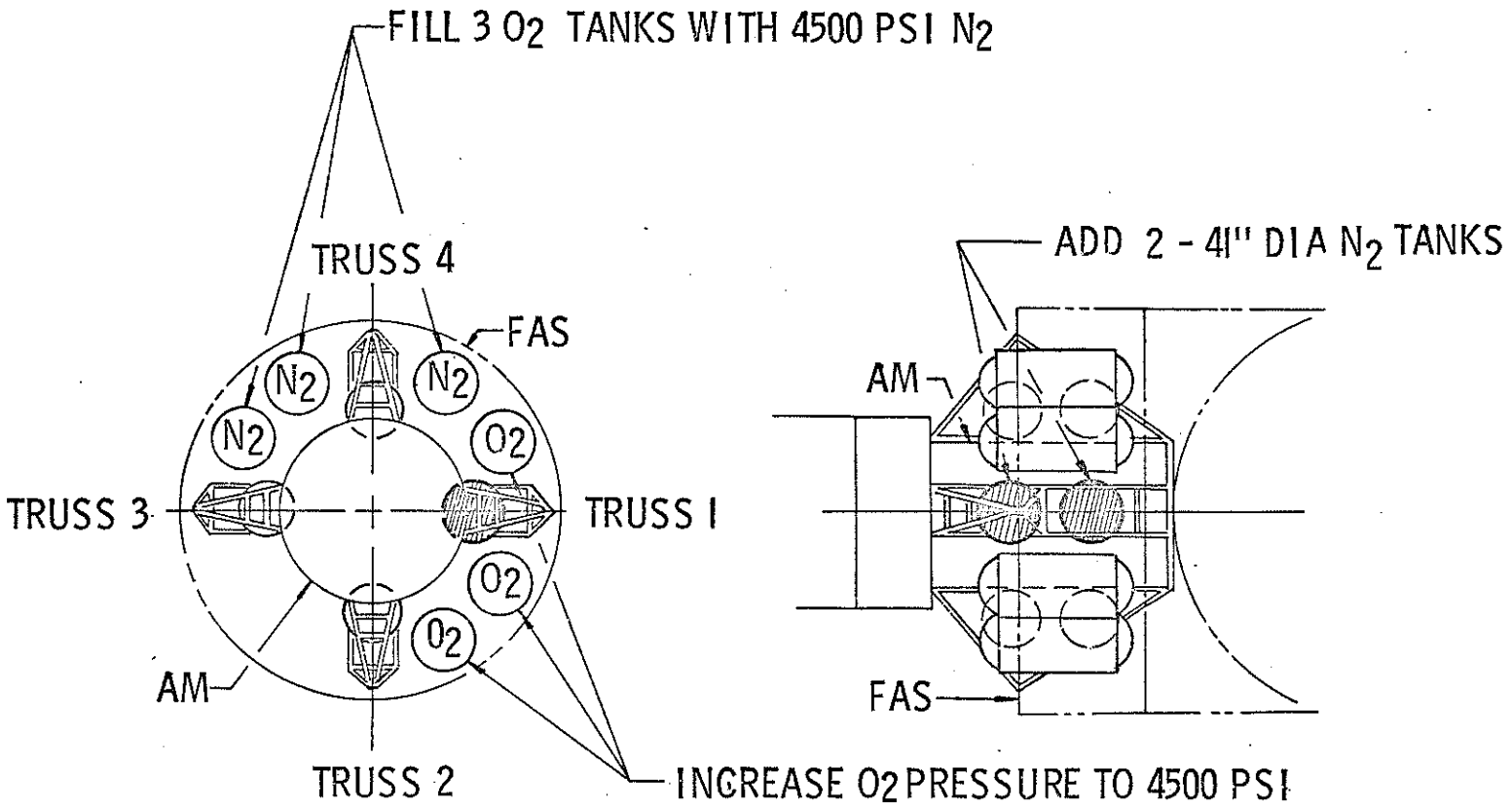
COOPERATIVE SPACE MISSION
ALTERNATE I (15 PSI) O_2 AND N_2 QUANTITIES

	O_2	N_2
CAPACITY AT 3000 PSIA AND 100°F (LBS)	---	1511
CAPACITY AT 4500 PSIA AND 100°F (LBS)	4008	3662
TOTAL CAPACITY (LBS)	4008	5173
RESIDUAL AT 300 PSIA AND 0°F (LBS)	342	542
USABLE AT NORMAL FLOW RATES (LBS)	3666	4631
CONSUMABLES REQUIRED* (LBS)	2635	4235
MARGIN (LBS)	1031	396

* BASED ON NOMINAL VALUES DERIVED FROM TEST DATA

MCDONNELL DOUGLAS CORPORATION

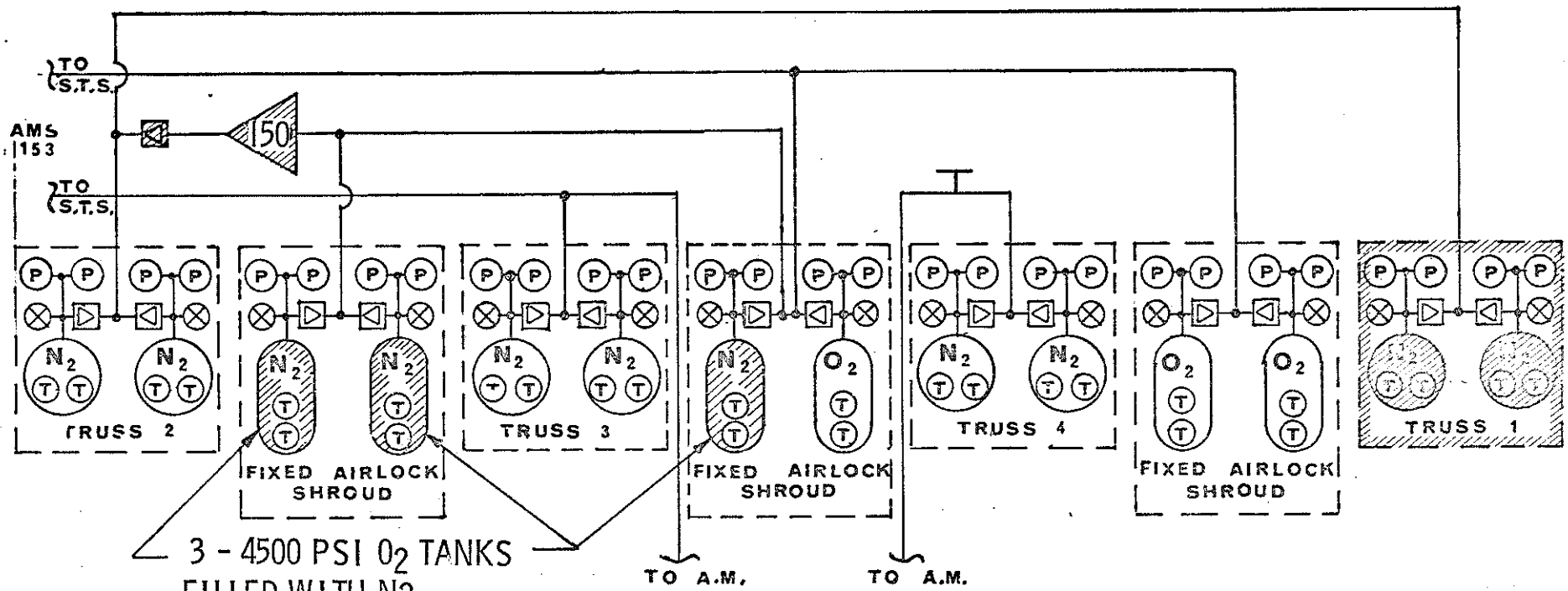
COOPERATIVE SPACE MISSION
ALTERNATE I
AM O_2 AND N_2 TANK ARRANGEMENT



▨ CHANGES FROM SKYLAB-A

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
O_2/N_2 GAS SYSTEM
ALTERNATE I (15 PSI)



MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
TEST PROGRAM FOR 15 PSIA ATMOSPHERE

- o MODIFY STRUCTURAL TEST ARTICLE
- o REPEAT PORTIONS OF STRUCTURAL TEST PROGRAM
  - o STRUCTURAL VERIFICATION
    - o STATIC PRESSURE
    - o VIBRATION
    - o COMPONENT TESTS
      - o WINDOW QUAL, LEAK, AND FAIL SAFE
      - o INTERNAL HATCH SEAL AND HANDLE FORCE
- o REPEAT PORTIONS OF $N_2 - O_2$ SYSTEM DEVELOPMENT TESTS
- o ADDITIONAL QUAL TESTING ON NEW OR REWORKED COMPONENTS
  - o CABIN PRESSURE REGULATOR, PRESSURE SWITCHES AND PRESSURE RELIEF VALVES
  - o CONDENSATE TANK

McDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION

OPTION

ALTERNATE II CHANGES (8 PSI)

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
STRUCTURE CHANGES
ALTERNATE 2 (8 PSI)

- INCREASING PRESSURE AFTER LAUNCH ELIMINATES MOST STRUCTURAL MODIFICATIONS
  - AM AND MDA VENTED DURING LAUNCH AND ACCENT
    - ELIMINATES INCREASED PRESSURE LOADS ACTING AT SAME TIME AS LAUNCH LOADS
    - MINIMIZES POSSIBLE STRUCTURAL BEEF-UPS AND OR TESTING
  - PRESSURE INCREASED FROM NEAR 0 TO 8 PSI IN ORBIT
  - NO MAJOR STRUCTURE MODIFICATIONS REQUIRED
    - MINOR AM BEEF-UP MAY INCLUDE MODIFICATIONS TO
      - EVA HATCH LATCHES
      - INTERNAL HATCHES
      - INTERNAL BULKHEADS
      - WINDOWS
      - INTER-COMPARTMENT DUCTS
    - MDA GOOD FOR 8 PSI
    - OWS GOOD FOR 8 PSI
    - CSM GOOD FOR 8 PSI

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
ALTERNATE 2 (8 PSI) CHANGES

- PROBLEM AREAS
  - SKYLAB PRESSURE MUST BE CONTROLLED TO 8 PSIA NOMINAL
  - HIGHER INTERNAL PRESSURE INCREASES CLUSTER OVERBOARD LEAKAGE RATES
  - O_2 PRE-BREATHING REQUIRED PRIOR TO EVA
- PROPOSED SOLUTIONS
  - NEW REGULATORS AND CABIN PRESSURE RELIEF VALVES REQUIRED TO PROVIDE 8 PSIA ATMOSPHERE
  - CONTROL AND DISPLAY RANGE CHANGES ARE REQUIRED FOR CABIN AND REGULATED PRESSURES
  - O_2 MASKS ARE NECESSARY FOR PRE-BREATHING OPERATION
  - APPROXIMATELY 1,300 POUNDS ADDITIONAL N_2 REQUIRED TO COMPENSATE FOR LEAKAGE

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
ALTERNATE 2 (8 PSI) O_2 AND N_2 CONSUMABLES

3 MEN-140 DAY MISSION AT 3.5 PSIA O_2, 4.5 PSIA N_2	GAS CONSUMABLES - LB			
	SPECIFICATION		NOMINAL *	
	O_2	N_2	O_2	N_2
METABOLIC O_2 (2.0 LB/MAN-DAY SKYLAB SPECIFICATION; 1.63 LB/MAN-DAY NOMINAL *)	840	---	685	---
LEAKAGE (24.31 LB/DAY SPEC; 16.56 LB/DAY NOMINAL *)	1582	1820	1080	1240
MOLECULAR SIEVE (5.56 LB/DAY SPEC; 4.44 NOMINAL *)	364	414	290	332
AM & MDA PRESSURIZATION (1764 FT^3 AT 40°F)	37	37	37	37
OWS PRESSURIZATION (9550 FT^3 AT 40°F)	198	198	198	198
EVA LOCK REPRESS (276 FT^3 AT 50°F WITH 6 REPRESS. CYCLES)	34	38	34	38
EVA PRE-BREATHING & EVA O_2 (PREBREATH - 1.9 LB/MAN-HR; EVA - 9.0 LB/MAN-HR)	140	---	140	---
EXPERIMENTS	119	138	119	138
OWS DRINKING WATER TANK PRESSURIZATION:	---	30	---	30
LEAKAGE FROM O_2 & N_2 SUPPLY TANKS & SYSTEM	8	9	8	9
TOTALS	3322	2684	2591	2022

* BASED ON SKYLAB A TEST DATA

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
ALTERNATE 2 (8 PSI) LEAKAGE DERIVATION

LEAKAGE SOURCE	FLOW RATE (LB/DAY)			
	SPECIFICATION 8.0 PSIA *	TEST DATA 5 PSID	NOMINAL 8.0 PSIA *	REMARKS
CSM	3.84	---	3.84	
SALYUT/MDA I/F	(1.92)	---	(1.92)	LEAKAGE CHARGED TO SALYUT
CSM/SOYUZ/MDA I/F	3.84	---	3.84	BASED ON CSM/ MDA I/F DATA
MDA DOCKING PORT	.32	---	.32	MDA HATCH CLOSED
MDA & AM	8.31	2.0	4.8	
OWS	8.0	1.1**	3.76	LEAKAGE + 50% + TRASH AIRLOCK
TOTALS	24.31	---	16.56	

* LEAKAGE ASSUMED TO INCREASE LINEARLY WITH PRESSURE (BASED ON ORIFICE CHOKE FLOW THEORY)

** LEAKAGE ONLY

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
ALTERNATE 2 (8 PSI) O_2 AND N_2 QUANTITIES

	O_2	N_2
CAPACITY AT 3000 PSIA AND 100°F (LBS)	3740	3105
RESIDUAL AT 300 PSIA AND 0°F (LBS)	456	387
USABLE AT NORMAL FLOW RATES (LBS)	3284	2718
CONSUMABLES REQUIRED * (LBS)	2591	2022
MARGIN (LBS)	693	696

* BASED ON NOMINAL VALUES DERIVED FROM TEST DATA

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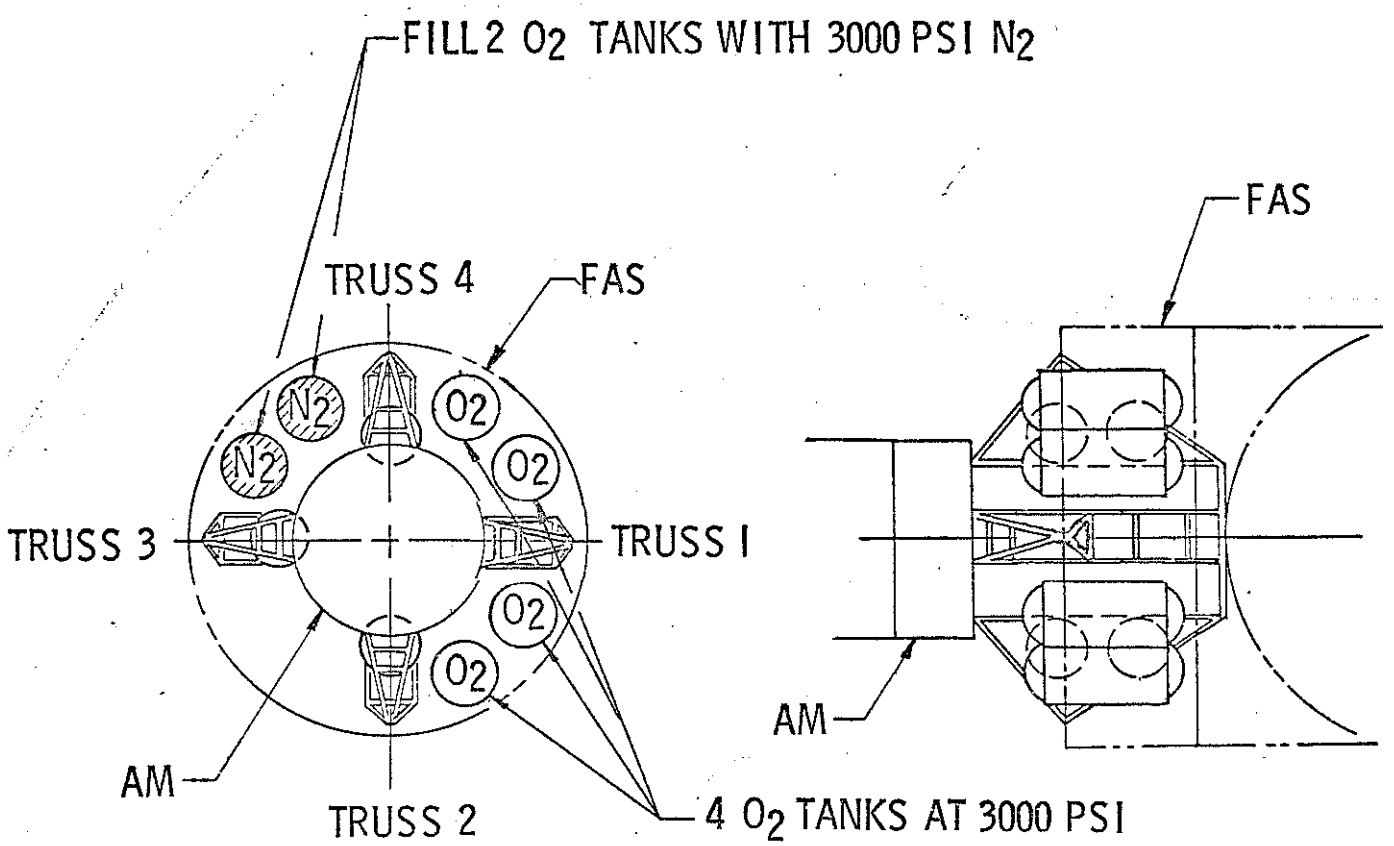
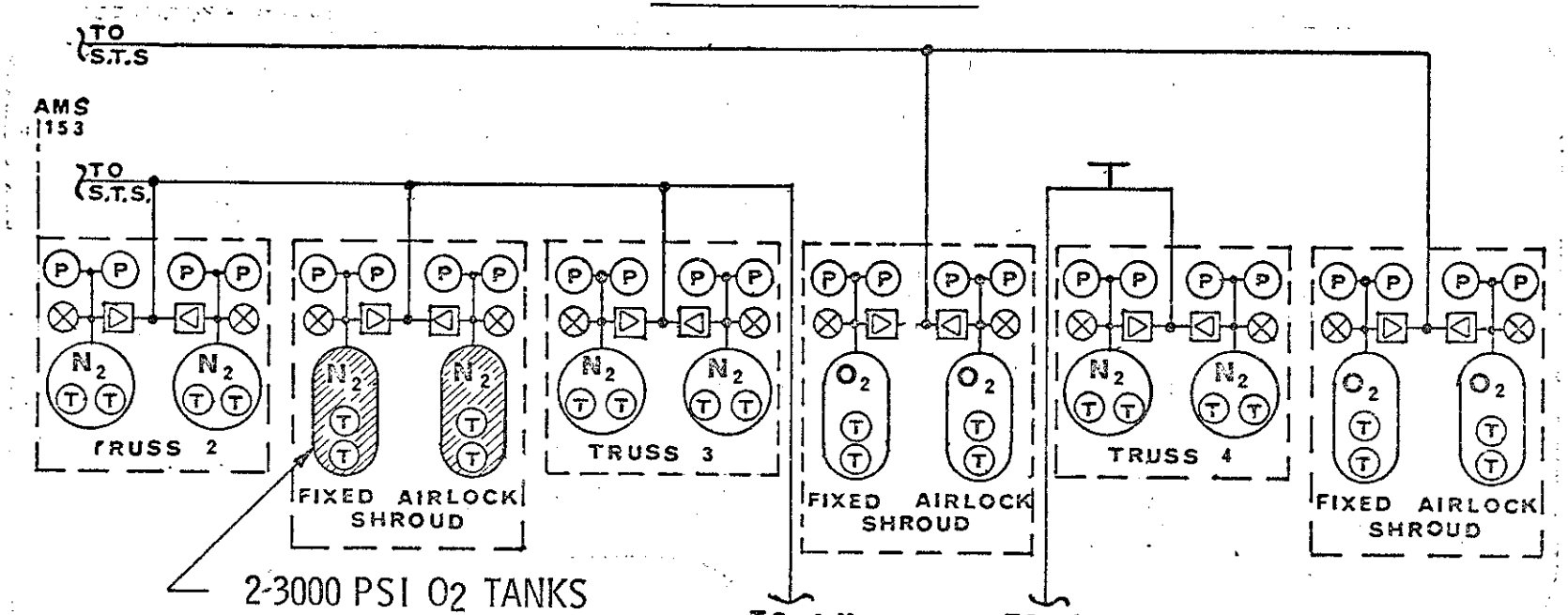
COOPERATIVE SPACE MISSION
O_2/N_2 TANK ARRANGEMENT
ALTERNATE 2 (8 PSI)



▨ CHANGES FROM SKYLAB-A

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
O_2/N_2 GAS SYSTEM
ALTERNATE 2 (8 PSI)



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COOPERATIVE SPACE MISSION
USSR ALTERNATE 2 (8 PSI) CHANGES

- SALYUT/SOYUZ CHANGES
  - UPRATE THERMAL CONTROL SYSTEM
    - CONVECTIVE HEAT TRANSFER REDUCED AT 8 PSI
  - REVISE TWO-GAS CONTROL SYSTEM
  - ADD O_2 MASKS FOR PREBREATHING
  - VERIFY CO_2 REMOVAL SYSTEM AND HUMIDITY CONTROL OPERATION AT 8 PSI
  - VERIFY NO EXCESSIVE ΔP IN PRESSURIZED SYSTEMS
  - REVISE CONTROLS AND DISPLAYS FOR TWO PRESSURE SYSTEM
  - REVISE C&W FOR TWO PRESSURE SYSTEM AND FOR GREATER FIRE MONITORING
  - REPLACE ALL MATERIALS WITH HIGH FLAME RATE AT 8 PSI WITH FIRE RETARDANT MATERIALS

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION

BASELINE AND ALTERNATE

CONSIDERATIONS

5 PSI (BASELINE)

15 PSI (ALTERNATE 1)

8 PSI (ALTERNATE 2)

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
OPERATING PRESSURE OPTIONS

- ATMOSPHERE SELECTION
  - 5 PSI (BASELINE)
    - US OPERATING PRESSURE
  - 15 PSI (ALTERNATE 1)
    - USSR OPERATING PRESSURE
  - 8 PSI (ALTERNATE 2)
    - COMPROMISE

CHANGES MUST BE MADE AS A RESULT OF PRESSURE DIFFERENTIALS

	ESTIMATED SYSTEM MODIFICATION RESULTING FROM OPERATING PRESSURE CHANGES - - PERCENT											
	SKYLAB			CSM			SALYUT			SOYUZ		
SYSTEM	5 PSI	15 PSI	8 PSI	5 PSI	15 PSI*	8 PSI	5 PSI	15 PSI	8 PSI	5 PSI	15 PSI	8 PSI
STRUCTURE	-	15	1	-	-	-	-	-	-	-	-	-
THERMAL	-	-	-	-	-	-	10	-	10	10	-	10
ECS	-	15	10	-	-	10	10	-	10	10	-	10
CONSUMABLES	-	5	2	-	-	-	-	-	-	-	-	-
CONTROL & DISPLAY	-	10	10	-	5	10	10	-	10	10	-	10
CAUTION & WARNING	-	5	5	-	5	5	10	-	10	10	-	10
IF ALL SYSTEMS (ELEC, COMM, G&C, ETC.) ARE CONSIDERED, THE SPACECRAFT CHANGES ARE ESTIMATED AT:												
TOTAL SYSTEM CHANGES		6	3		1	3	5		5	5		5

* CSM IS ISOLATED FROM 15 PSI WHILE DOCKED

COOPERATIVE SPACE MISSION
PROS AND CONS OF 15 PSIA ATMOSPHERE

PRO

MEDICAL

- THERE IS AN IMMENSE AMOUNT OF HISTORICAL DATA AT ESSENTIALLY SEA LEVEL PRESSURE (14.7 PSIA). THIS BASELINE DATA MAY AID UNDERSTANDING ANY BIOMEDICAL CHANGES WHICH DO OCCUR IN ORBIT.

FLAMMABILITY

- INCREASED NITROGEN CONTENT HAS A COOLING EFFECT WHICH REDUCES THE FLAMMABILITY POTENTIAL.

CON

MISSION OPERATIONS

- EVA PURE OXYGEN PREBREATHING TIME (TO PURGE BLOOD OF NITROGEN) GOES UP WITH INCREASING NITROGEN PRESSURE.

WEIGHT

ATMOSPHERE SUPPLY - ATMOSPHERE LEAKAGE INCREASES WITH INCREASING PRESSURE.

STRUCTURE - WEIGHT INCREASES WITH INCREASING PRESSURE.

EVA LOSS

- INCREASED PRESSURE CAUSES GREATER GAS LOSS WITH EACH EVA.
- PRE-BREATHING INCREASES O_2 REQUIREMENTS

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
PROS AND CONS OF 8 PSIA ATMOSPHERE

PRO

FLAMMABILITY

- INCREASED NITROGEN CONTENT HAS A COOLING EFFECT WHICH REDUCES THE FLAMMABILITY POTENTIAL

CONS

MISSION OPERATIONS

- EVA PURGE OXYGEN PREBREATHING TIME (TO PURGE BLOOD OF NITROGEN) GOES UP WITH INCREASING NITROGEN PRESSURE

WEIGHT

ATMOSPHERE SUPPLY - ATMOSPHERE LEAKAGE INCREASES WITH INCREASING PRESSURE

STRUCTURE - WEIGHT INCREASES WITH INCREASING PRESSURE

EVA LOSS - INCREASED PRESSURE CAUSED GREATER GAS LOSS WITH EACH EVA AND PRE-BREATHING INCREASES O_2 REQUIREMENTS

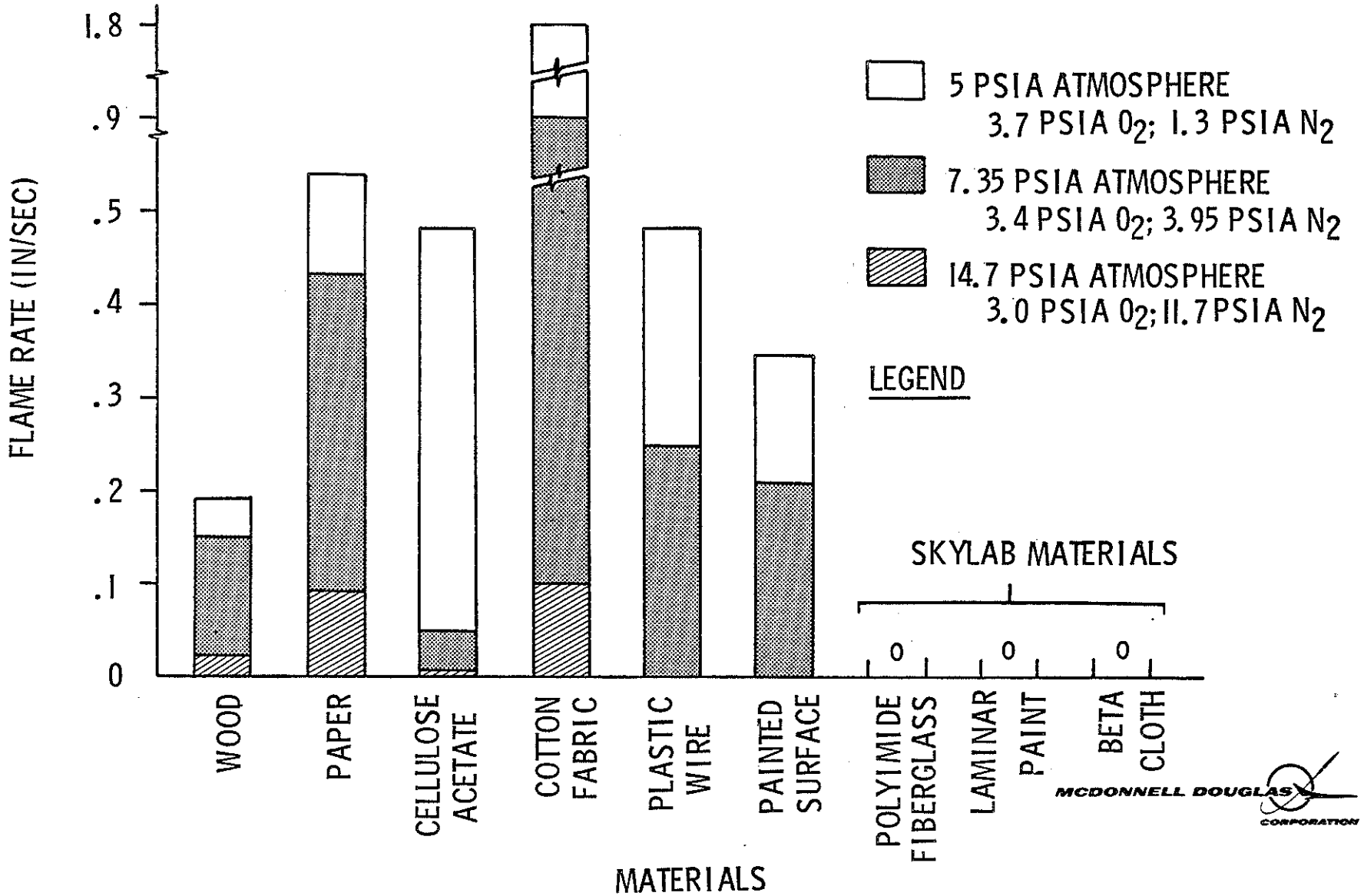
MEDICAL

- LOSS OF 14.7 DATA COMPROMISES MEDICAL EXPERIMENT PROGRAM

MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
FLAMMABILITY

- HIGHER N_2 DILUENTS RESULT IN LOWER FIRE HAZARDS

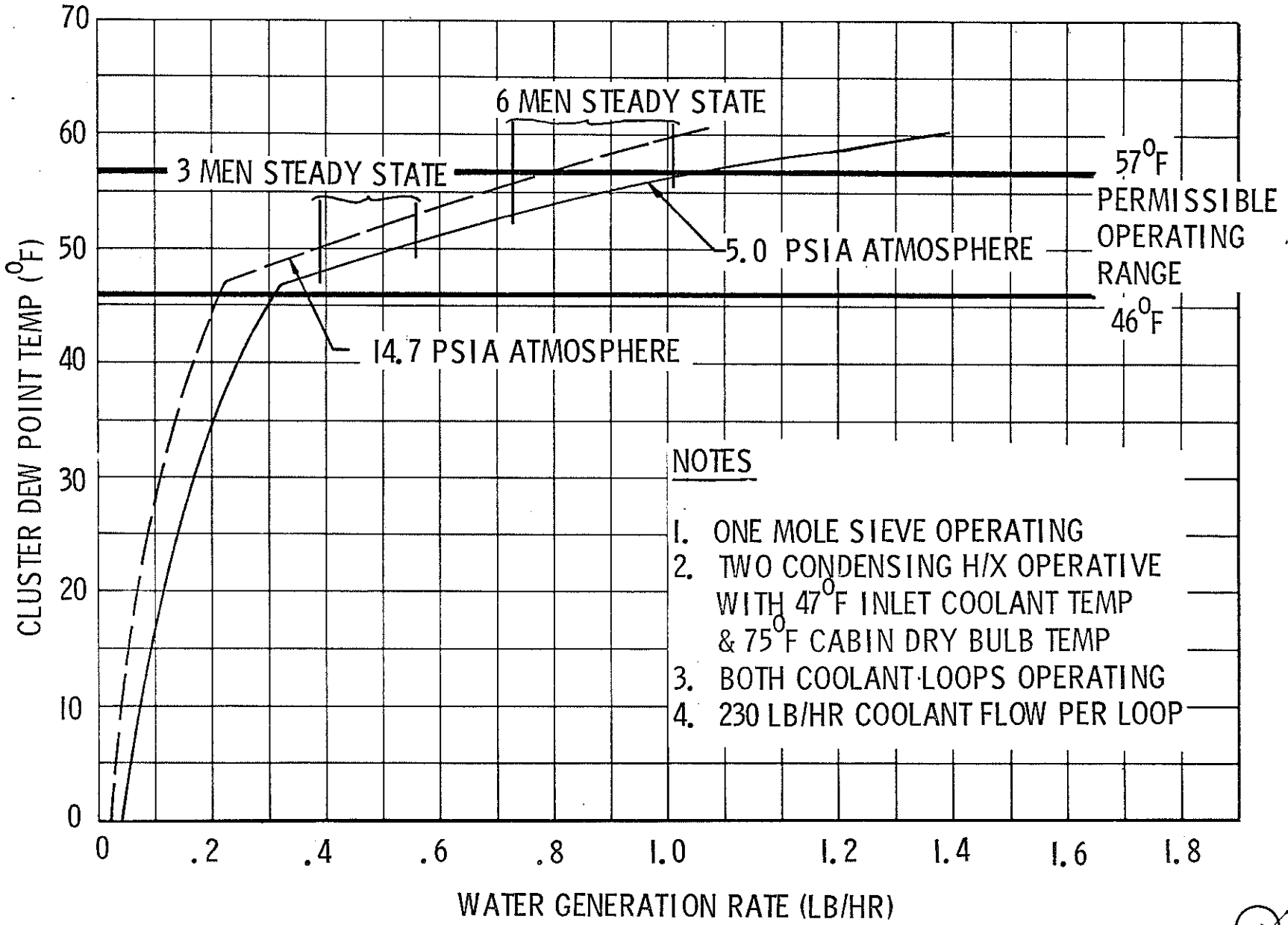


COOPERATIVE SPACE MISSION
TCS EFFECTS OF 15 PSIA ATMOSPHERE

- THERMAL CONTROL IS BETTER
  - FAN PERFORMANCE INCREASED
    - FEWER FANS NEED TO BE OPERATED DUE TO HIGHER MASS FLOW RESULTING IN IMPROVED CONVECTION
      - NOISE LEVEL IS REDUCED

MCDONNELL DOUGLAS CORPORATION

CLUSTER DEW POINT TEMPERATURE RANGE: 5 VS 14.7 PSIA ATMOSPHERE



MCDONNELL DOUGLAS CORPORATION

COOPERATIVE SPACE MISSION
WEIGHT SUMMARY

	SKYLAB A	5 PSI	15 PSI	8 PSI
AIRLOCK MODULE	49584	50038	53724	49835
BASIC AIRLOCK MODULE	16808	16880	18924	17071
ATM DEPLOYMENT ASSEMBLY	4055	4055	4055	4055
FIXED AIRLOCK SHROUD	28721	29103	30745	28866
MULTIPLE DOCKING ADAPTOR	13554	13707	14157	13707
ORBITAL WORK SHOP	77302	77302	77302	77302
INSTRUMENT UNIT	4408	4408	4408	4408
APOLLO TELESCOPE MOUNT	24641	24641	24641	24641
TOTAL	169489	170096	174232	169893

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